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The Renory Viaduct on the Fexhe-le-Haut-Clocher to Kinkempois line of the Belgian Railways [1],

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Figs. 1 to 35, p. 1920 to 1975.

INTRODUCTION.

For the sake of clearness, we have divided the following report into two parts, first the study of the scheme, and then its execution.

The second part will be unavoidably longer than the first owing to the fact that it includes numerous details which, though not of paramount importance, will still be useful to those of our young colleagues who may one day have to carry out a similar task, perhaps not similar as a whole, but at least in many of its details.

Moreover, in this second part, the construction, it has been necessary to draw up many working schemes, which though not attaining the amplitude of the scheme for the viaduct itself, have excited some interest and, we believe, have been solved with much elegance.

Our aim has been to make the report useful from both the practical and theoretical points of view.

We take this opportunity of offering our excuses for the length of our report. We have attempted to make it more acceptable by illustrations as copious in number as the scope of the article permitted, the object of these illustrations being to make it as complete and as clear as possible.

FIRST PART.

The Scheme.

1. — The reason for the work (fig. 1).

The line from Fexhe-le-Haut-Clocher to Kinkempois is being constructed mainly to avoid the inclined plane connecting the Ans plateau with the valley of the

(1) Translated from the French.

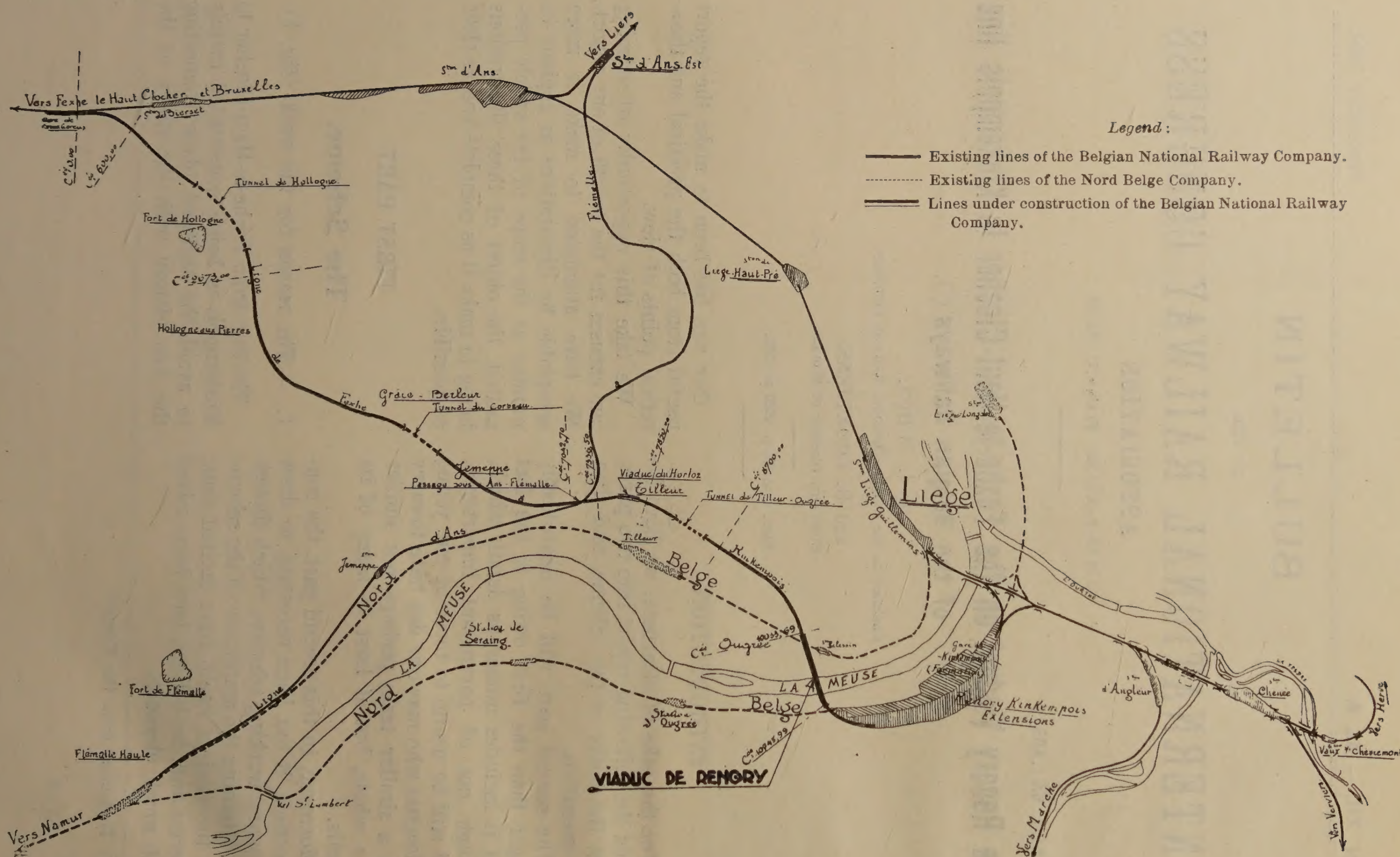


Fig. 1. — New line from Fexhe-le-Haut-Clocher to Kinkempois. — Diagrammatic plan.

Meuse with a difference in level of about 100 m. (328 feet).

The gradient of this inclined plane in certain places is of the order of 30 mm. per metre (1 in 33), and results in the working of this important branch of the system being very difficult from the point of view of both passenger and goods traffic.

In order to reduce the ratio of working expenses to gross receipts, the maximum gradient of the line under construction, which is mainly for goods traffic, has been fixed at 10 mm. per metre (1 in 100).

The passenger trains alone will continue to use the inclined plane, a fortunate circumstance as regards the arrangement of the Liége-Guillemins station, now being carried out.

The topographical situation of this station, wedged in between the mountain side and the town, only allows in fact the addition of a few lines to the arrival lines for the trains, and whatever were to be done, unless at an expenditure out of all proportion to the results to be obtained, there would always have been a lack of space from the point of view of the working of the line.

Starting from the neighbourhood of Fexhe-le-Haut-Clocher, where an important train formation station will provide connection with the international Brussels-Liége line, the new line terminates at the station of Kinkempois, and before reaching this station crosses at a height of 20 m. (66 feet) the dense industrial district of Sclessin, the Meuse and the port of Renory by means of a viaduct more than 700 m. (2 297 feet) long.

This line, about 12 km. (7.5 miles) long has also necessitated the construction of numerous other works, among the more important of which are three tunnels and a steel viaduct.

The line will cost approximately 125 million francs.

II. — Reasons for the type of structure adopted.

The type approved by the Permanent Way Department, after various comparative studies, is the three-hinged arch of non-reinforced concrete.

Whatever the type adopted, the steel floor bridge would have difficulty in competing with the arched bridge, even from the point of view of first cost.

The local conditions, resulting from the crossing of the Nord-Belge Company's line from Liége-Guillemins to Namur, and the crossing of the network of busy streets of the Sclessin district, did not allow the cantilever type of bridge to be adopted.

Moreover, this type could only be used over the Meuse, and then under the unfavourable conditions of the distributions of the supports from the point of view of the dead weight of the main girders. The curved section of the viaduct only accentuated the difficulties.

In addition, it is a general rule, except in new countries, not to use steel except in cases of absolute necessity.

Masonry, the life of which is practically unlimited, reduces the upkeep expenses to a minimum and allows the loads passing over it to be increased readily without requiring strengthening. An important consideration for a railway bridge is that the considerable inertia of the mass of the arches adapts itself well to the dynamic stresses of heavy traffic.

Finally, the cost of renewing the steel bridges would have been very great owing to their high level, and it would not have been possible to avoid interrupting the traffic.

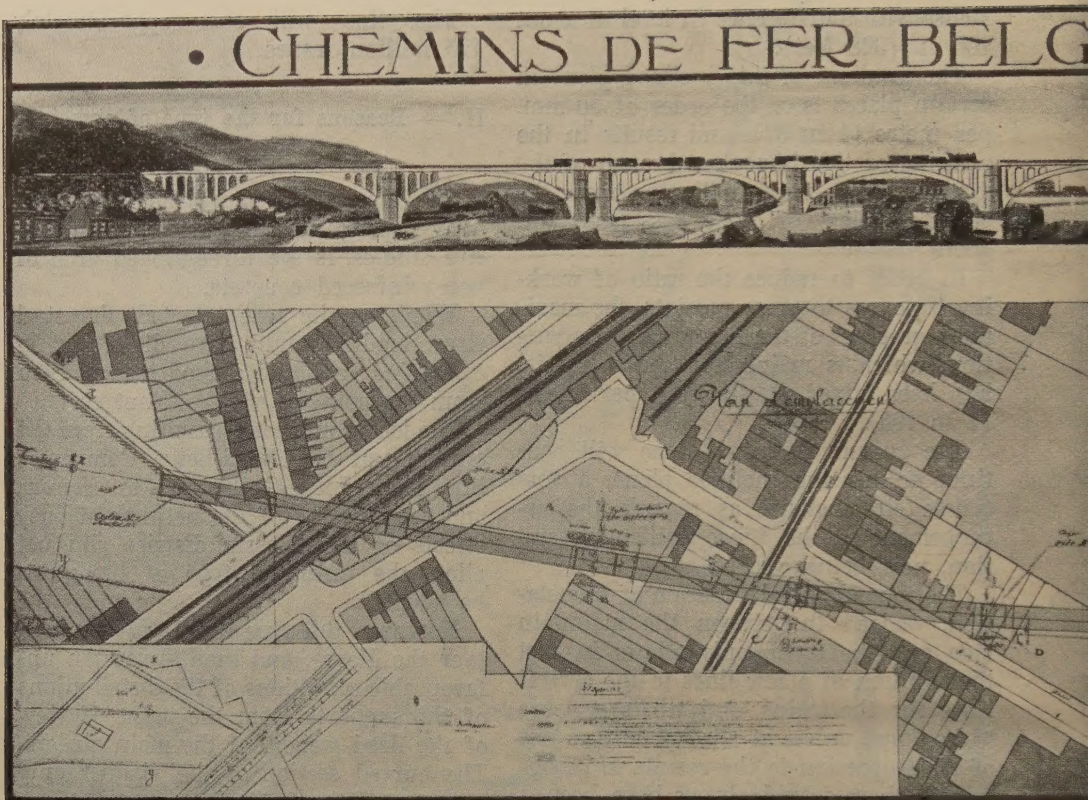


Fig. 2. — Belgian

These are the principal factors which determined the adoption of the arched bridge of masonry.

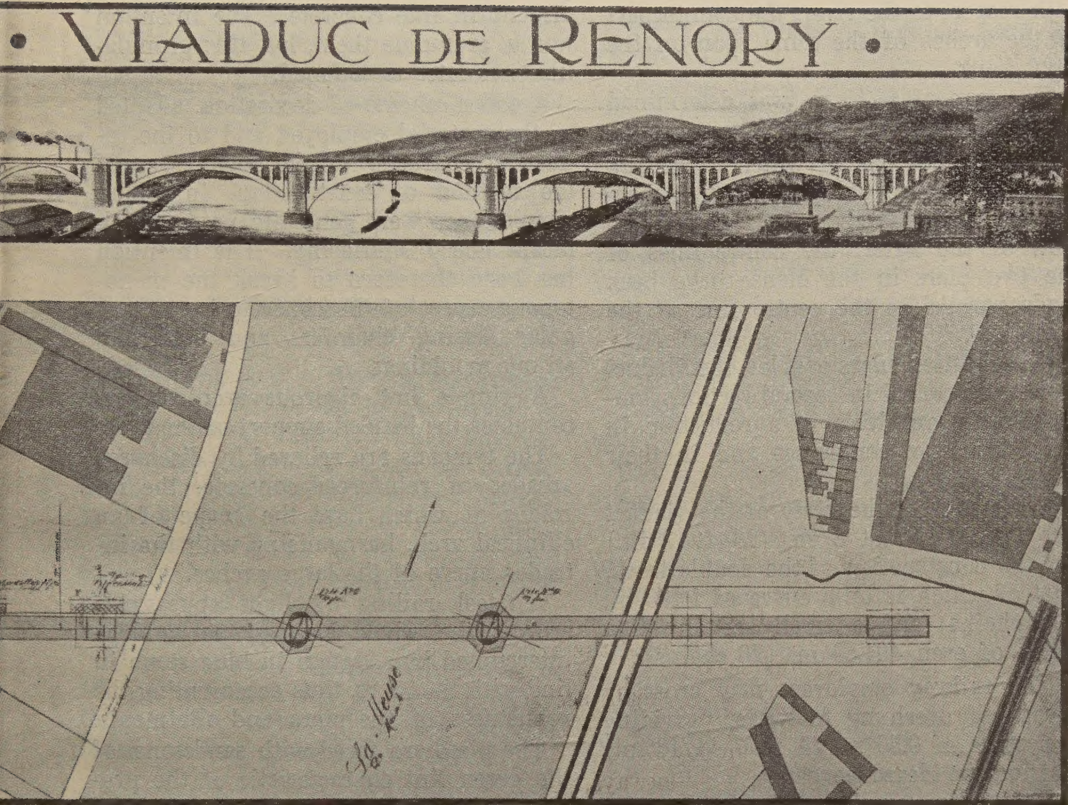
Since it is possible that the Renory viaduct may, in the future, be subjected to the effects of mining subsidences, although only to a slight extent, the three-hinged type of arch suggested itself, in view of the fact that the elastic stability of the arch is independent of any slight movement of the supports. The three-hinged arch alone provides security in the case of a sub-soil which does not inspire much confidence.

Moreover, in this system of arches, temperature has no effect on the stress existing in the structure. An important advantage is that the arch is isostatic, and the curve of pressures can be traced with certainty.

III. — Material.

The material adopted for the construction of the arches is non-reinforced concrete. While being economical at the present time, it affords sufficient security from the point of view of strength.

In an extensive piece of work, the quality of the cement, the manufacture of



Renory viaduct.

the concrete and its use may be controlled in an effective manner.

As regards shrinking, a weak point with this material, its effect is almost nil in actual practice, the concreting being effected by separate voussoirs extending from one wall to the other of the arches, the joints being ultimately rammed full of strong dry cement mortar.

IV. — General arrangement of the viaduct.

The viaduct is composed of nine arches of a span of 61.40 m. (201 ft. 6 in.) and one arch of a span of 34 m. (111 ft. 6 in.).

Originally the crossing of the port of Renory (right bank of the Meuse) was effected to have been by 4 arches of 34 m. (111 ft. 6 in.) span, but an agreement with the Department of Roads and Bridges enabled two of these to be replaced by an embankment, obviously less expensive.

The two remaining arches were finally replaced by a single arch of 61.40 m. (201 ft. 6 in.).

This is the reason for the single arch of 34 m. (111 ft. 6 in.) on the left bank of the Meuse, which forms in the project,

with respect to the river, the counterpart of the arches of the same span on the right bank.

The span of 61.40 m. was determined by local conditons.

Three spans, one of which is central, cross the Meuse obliquely, but the arches spring squarely. To facilitate the flow of the water, the centre lines of the two piers in the Meuse have been made parallel to the centre line of the river.

Four bastion piers enabled the viaduct to be constructed in several sections longitudinally, resulting in a reduction in the number of centerings and in their cost.

The width of the body of the viaduct has been fixed at 8 m. (26 ft. 3 in.) for the construction of the double track, part of which is on a curve of 1 100 m. (55 chains) and a small section on a curve of even 401.50 m. (20 chains).

The railway employees may cross by means of overhung footways, providing a passage of 0.50 m. (1 ft. 7 11/16 in.) outside the clearance gauge.

Later, an overhung footbridge for pedestrians was added over four arches. Access to this on the left bank is gained by a very high staircase, which certainly does not make it very practicable. Nevertheless, the paucity of means for crossing the Meuse in such an important industrial centre justifies the decision made by the Department of Roads and Bridges and the industrialists of the neighbourhood.

On the right bank, the footbridge is connected to the port by a path, with a gradient of 10 % (1 in 10), formed along the side of the embankment.

From the decorative and aesthetic point of view, the aim above all has been sincerity by avoiding coverings. With this in view, the walls have been finished directly in fine concrete. The intention was to granulate them, but this granulation was later abandoned.

A sober scheme of decoration, adapted to the material employed and to the industrial character of the region, recalls the method of construction, in which simple lines were generally used, which meant cheap shuttering. The intention has been therefore to break the monotonous aspect of the concrete by rectangular fluting, chamfers and bold and strong mouldings.

A simple but vigorous archivolt accentuates the banded support of the arch.

The tympans are relieved by discharge arcades of reinforced concrete, the intrados of which have the shape of an elliptical arch, harmonising with the intrados curve of the large arches.

A steel railing of light appearance crowns the whole arrangement and is interrupted by a design in blue stone in line with the piers, thus accentuating the robustness of the piers and abutments.

The piers are faced with sandstone, of the green tint characteristic of the products of the Gileppe valley, with belts of building stone.

After discussion, the cast steel hinges were left visible. It was, in fact, decided that they should be left showing in order to reveal the technical design of the work and to justify to the experienced eye the fusiform shape of the arch sections.

V. — The calculation of the arches.

a) *Dead load.* — After a number of trials the neutral axis of the arch in the zones of maximum bending moments under a moving load was eventually fitted in the funicular polygon of the dead loads.

In this way, the dead weight practically gives rise only to compression and

to slight bending moments favourable for resisting moving loads.

It was possible to adopt for the curve of the intrados an algebraically defined curve composed of a parabola of the second degree, joining with a parabola of the sixth degree, and having at the point of juncture the same tangent and the same radius of curvature (the same osculatory circle). This last condition is necessary from the point of view of appearance.

b) *Moving load.* — The two tracks were assumed to be loaded to the extent of 10 t. per linear metre (3 Engl. tons per linear foot), a loading which was accepted for the calculation of arched bridges at the time the project was drawn up.

The stresses due to the moving load were studied by the classical method of influence lines. The arch is nowhere under tensile stress.

The maximum compressive stress is 40 kgr. per cm² (569 lb. per sq. inch), thus readily allowing for any increase in the moving loads in the future.

V. — Composition of the concrete.

The concrete of the foundations is composed of :

200 kgr. (440 lb.) of ordinary artificial Portland cement;

1 000 litres (35.2 cubic feet) of washed Meuse gravel, 0 to 60 mm. (0 to 2 3/8 inches);

125 litres (4.4 cubic feet) of Rhine sand.

The concrete of the superstructure is composed of :

350 kgr. (772 lb.) of ordinary artificial Portland cement;

1 000 litres (35.2 cubic feet) of washed Meuse gravel, 0 to 60 mm. (0 to 2 3/8 inches);

about 125 litres (4.4 cubic feet) of Rhine sand.

In some places, where the closeness of the reinforcement gave rise to the fear that the concrete might lack compactness owing to the difficulty of ramming, Meuse gravel of 0 to 30 mm. (0 to 1 3/16 inches) was used (for example, between the reinforcement of the hinge bearings).

The caulking joints were filled with the following mixture :

1 000 litres (35.2 cubic feet) of Rhine sand;

600 kgr. (1 320 lb.) of ordinary artificial Portland cement.

Test cubes, 30 cm. (11 13/16 inches) of side, and made with concrete taken from the concrete mixer (consequently, of the ordinary compositon and manufacture, and not laboratory concrete) gave for the concrete having 350 kgr. of Portland cement, 28 days old, mean strengths of 220 kgr. per cm² (3 129 lb. per sq. inch) with a minimum of 175 kgr. per cm² (2 489 lb. per sq. inch).

As regards the joints, a joint 6 cm. (2 3/8 inches) thick, 0.50 m. (19 11/16 inches) long and 2.50 m. (8 ft. 2 7/16 in.) deep, and in the vertical position (and therefore normal) was concreted by way of test. Nine cubes of 5-cm. (2 inches) side were cut in the laboratory from the slab thus obtained.

These cubes, tested after 28 days, gave an average crushing strength of 831 kgr. per cm² (11 819 lb. per sq. inch) with a minimum of 692 kgr. per cm² (9 842 lb. per sq. inch) and a maximum of 962 kgr. per cm² (13 683 lb. per sq. inch).

The quantity of sand incorporated in the concrete mixtures was subject to variation according to the degree of fineness of the gravel as received.

SECOND PART.

Execution.

General installation of the works and supply of material.

The scarcity of labour and its demands, the desire to conduct the work rapidly and scientifically, made it necessary to mechanise the execution of the work as far as possible.

The small capacity of the station at Sclessin resulted in the contractors deciding to receive the greater portion of the material by water.

Hence, the gravel, sand and cement arrived by way of the river Meuse. The steel, plant and timber alone came by rail, these last-mentioned supplies constituting but a small proportion of the total tonnage.

Moreover, the land placed at the disposal of the contractors was quite insufficient. This fact resulted in sites being rented at high prices and necessitated the plant being arranged so as to utilise the available space as rationally as possible.

The arrangement of the whole work, as shown in the diagrammatic plan in figure 3, will thus be readily understood.

An openwork staging, constructed of spars and half spars (spars sawn in two along their length) nailed with their flat face upward, was erected at right angles to the Meuse, for a length of about 200 m. (656 feet).

The cement stores were placed at the far end of the staging.

The floor of the footway sloped half a centimetre per metre (1 in 200) toward the yard.

The gravel and sand arriving in barges under the staging were unloaded by means of an automatic electric grab. The material was emptied into Decauville trucks from a hopper. The trucks were run along the staging and tipped at any desired point.

The stores was placed below the tracks, resulting in a double saving owing to the gain in space and to the fact that picking up from the dumps, always a very costly process, was avoided.

The gravel was taken up by another grab which unloaded it into bins. The measuring trucks, of a special shape with a view to economical handling, were filled under these bins.

The position of the bin, between the concrete mixers and 6 m. (20 feet) from each of them, reduced the haulage to a minimum.

A bin was not provided for the sand, the use of unsorted gravel having considerably reduced the proportion of sand, and it was found to be simplest to wheel it in wheelbarrows to the concrete mixer.

The cement was unloaded by the derrick on the bank onto plates placed on flat trucks running along the staging, and was thus conveyed to store sheds. It was discharged in the upper portion of the sheds, and was placed in position by allowing it to fall down portable chutes. It was taken from the lower portion of the sheds for concreting.

This plant, which was larger on the left bank of the Meuse than on the right bank, supplied two concrete mixers of the « Roll » pattern, having a capacity of 1 m^3 (1.3 cubic yards); there was one concrete mixer on the right bank.

The whole of the mechanical plant in normal working order necessitated not less than 60 electric motors of outputs varying from 0.25 to 90 H. P.

The power installed exceeded 1 000 H.P. Although all the appliances were not working at once, the sub-station erected by the contractors sometimes proved to be too small.

This sub-station comprised two 200-

K. V. A. transformers, each with equipment transforming the current received at 6 300 volts down to three-phase current at 220 volts.

A synchronised asynchronous set, running day and night, was also installed in this sub-station, being intended to increase the power factor of the installation, which was unavoidably low with plant being continually started up, and to avoid the high cost resulting from this insufficient power factor.

The mixed concrete was transported along Decauville tracks for use at places in the vicinity of the concrete mixers, and by five motor tractors for distant places and for places separated by main roads with heavy traffic.

It would have been too costly to instal an aerial conveyor, besides being complicated by the curve of the viaduct.

II. — Foundations.

1. *Shape of the foundations.*

The foundations shown in the plans of the railway administration had a rectangular shape. They were to descend to the shale which was to be loaded to 10 kgr. per cm² (142.3 lb. per sq. inch).

The method of execution was left to the choice of the contractor, except for the piers in the Meuse, where the use of compressed air caissons was prescribed.

The nature of the ground, which was almost uniform, was as follows :

From 0 to 1 m. (0 to 3 ft. 3 3/8 in.) vegetable mould.

From 1 to 10 m. (3 ft. 3 3/8 in. to 32 ft. 9 in.) gravel with scattered boulders attaining 0.75 m³ (26.5 cubic feet).

At 10 m. (32 ft. 9 in.) sound shale covered with 30 to 40 cm. (12 to 16 inches) broken shale.

This shale belongs to the coal-bearing strata (carboniferous) and in some places is replaced by soft sandstone.

At a depth of 3 m. (10 feet) water was encountered. The flow of this water was as abundant at places remote from the Meuse as in the river, the latter having an underground bed wider than the visible bed.

The contractors decided to construct the piers on the banks behind the protection afforded by cofferdams of metal sheet piles.

The ordinary piers had a foundation area of about 15 m. × 15 m. (49 × 49 feet). The end abutments had a foundation area of 11.5 m. × 22 m. (37 ft. 9 in. × 72 ft.).

The difficulty of lining excavations of such large dimensions as these subjected to thrusts of a corresponding order of magnitude will be understood at once. The contractors then proposed, at the instigation of their consulting engineer, Mr. Caquot, to the railway administration to substitute an oval shape for the rectangular shape, and this proposal was accepted. The lining of the excavations thus became much easier.

The elimination of the angles offered the additional advantage that certain existing structures could be avoided.

The only condition which was imposed was that the maximum load on the ground, as originally adopted, was not in any case exceeded.

After fixing the dimensions of the new foundations, the lining for the largest of them was studied. Proceeding in this manner, an oval having axes of 19 m. and 16.80 m. (62 ft. 4 in. and 55 ft. 1 1/2 in.), respectively, was adopted.

In this way, even for the largest foundation, a margin of 0.50 m. (1 ft. 11/16 in.) was left between the piles and the concrete which was to come, thus allow-

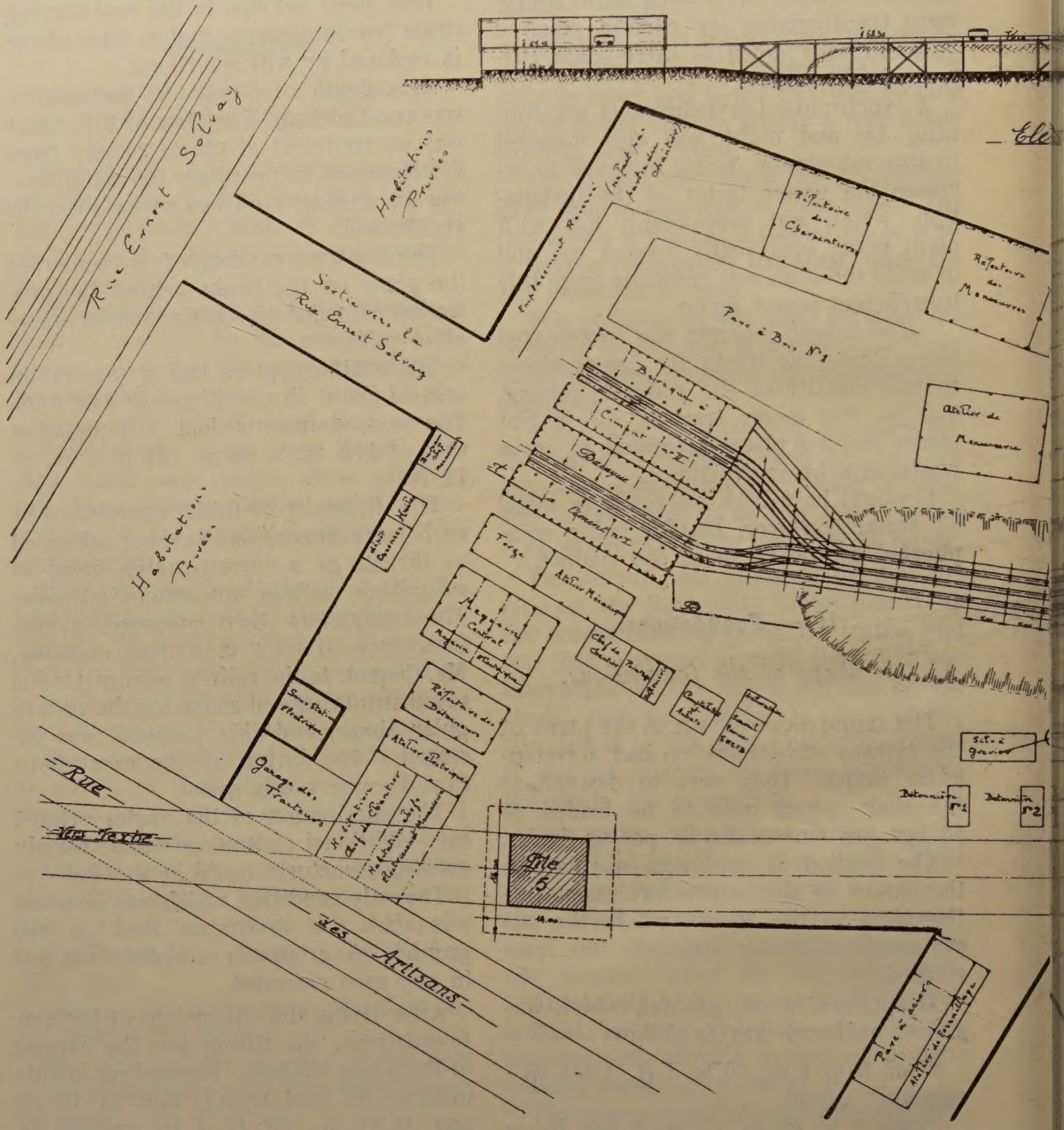
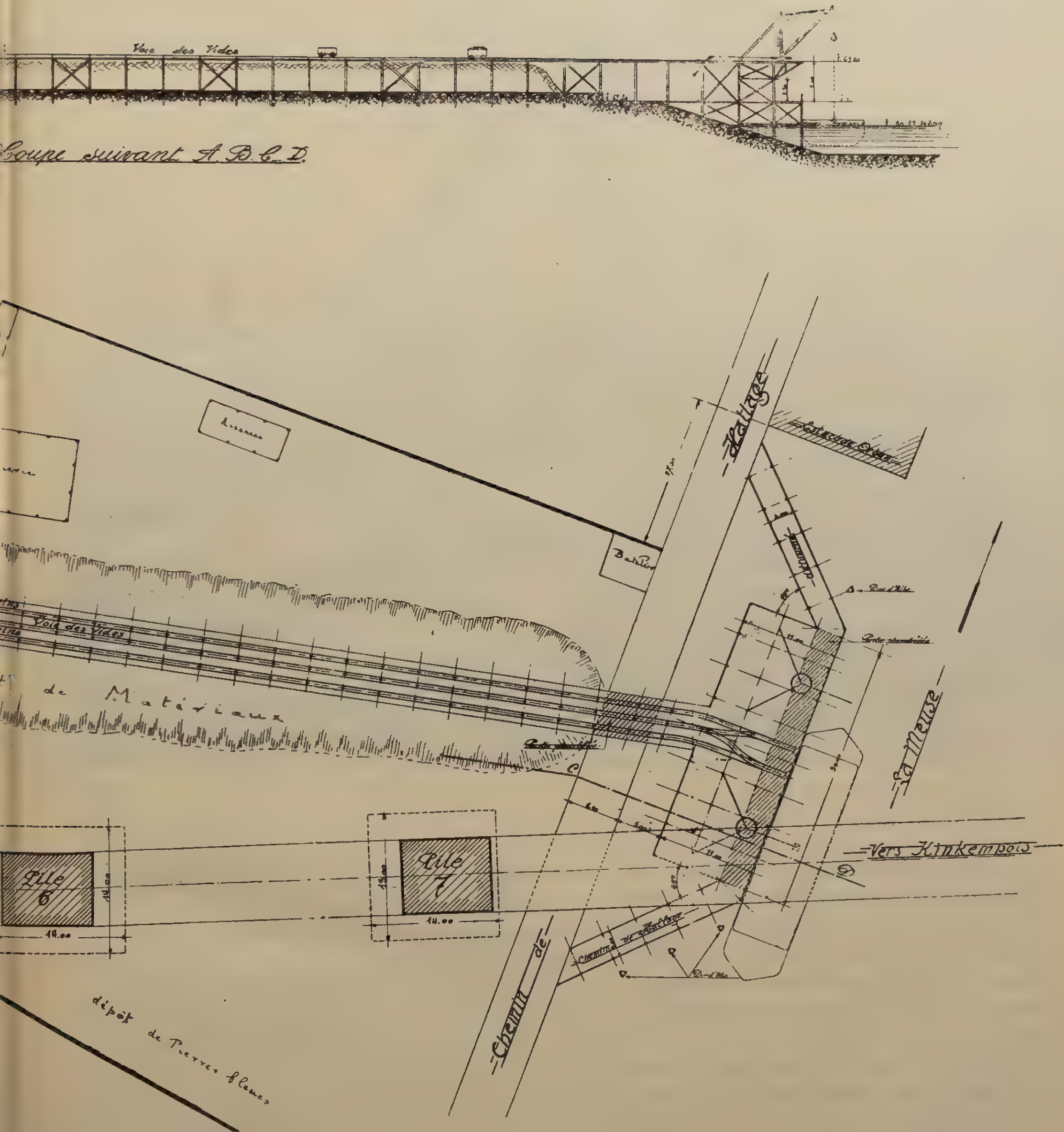


Fig. 3. — Renory Via

Explan

Aisances = Latrines. — Atelier de menuiserie = Joiners' shop. — Atelier électrique = Electricians' shop. — Baraque à cim Chef de chantier = Works foreman. — Chemin de... = Road from... — Chemin de halage détourné = Diverted towing — Elevation. Coupe suivant ABCD = Sectional elevation along ABCD. — Emplacement réservé, etc. = Reserved site (n tation chef de chantier = Works foreman's house. — Habitation chefs électriciens, etc. = Foreman electrician's and Magasin électrique = Electrician's stores. — Parc à acier, etc. = Steel stockyard and scrap. — Parc à bois = Timber ya refectory. — Réfectoire des manœuvres = Labourers' refectory. — Réfectoire des monteurs = Fitters' refectory. — pleins = Track for full wagons. — Voies des vides = Track for empties.



Central works, left bank.

rench terms :

ent shed. — Bateliers = Bargemen. — Bétonnière = Concrete mixer. — Bureau chef mécanicien = Foreman mechanic's office. – Comptabilité et achats. — Accounts and purchases. — Dépôt essences, huiles = Petrol, oil stores. — Dépôt de matériaux = Stocks. part of the works). — Forge, atelier mécanique = Smithy, machine shop. — Garage des tracteurs = Tractors' garage. — Habi- echanic's house. — Habitations privées = Private houses. — Infirmerie = Ambulance. — Magasin central = Central stores. — ture = Painting. — Pile = Pier. — Réfectoire des bétonneurs. — Concreters' refectory. — Réfectoire des charpentiers = Joiners' Sawmill. — Silo à gravier = Gravel bin. — Sous-station électrique = Electric sub-station. — Vers — Towards. = Voies des

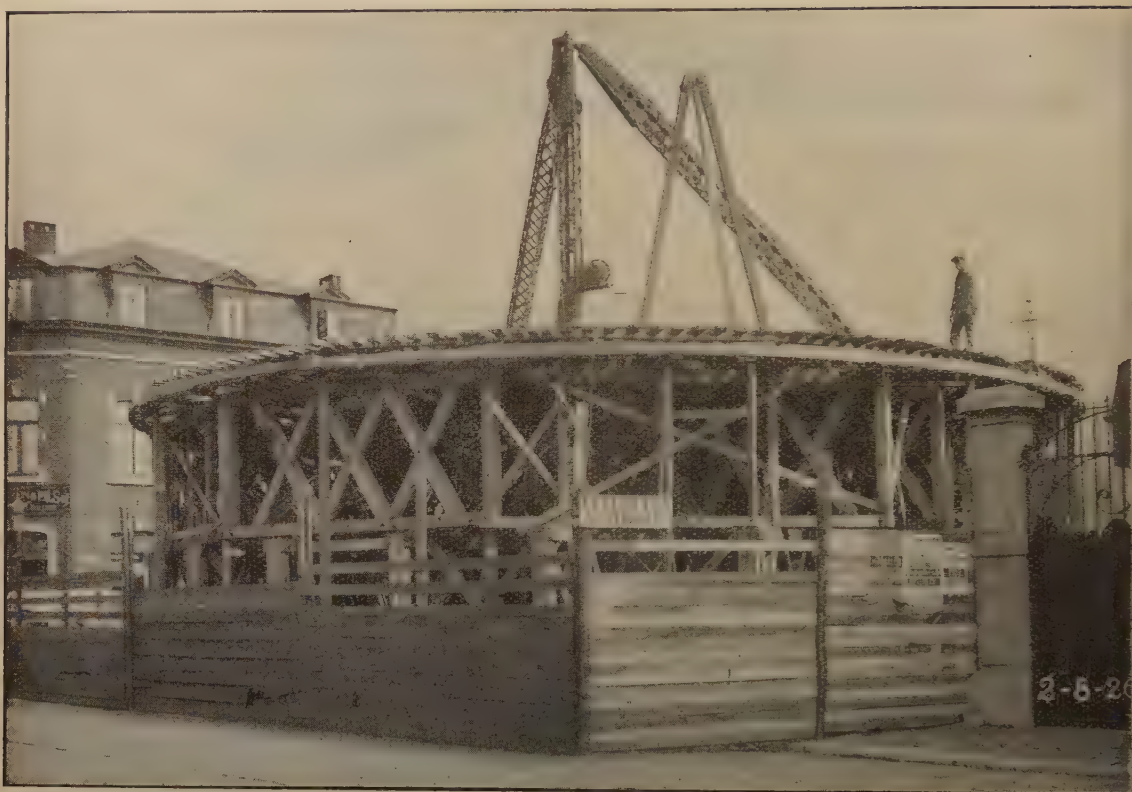


Fig. 4.

ing a second barrier of piles to be driven in case of loosening of the piles or considerable deterioration which might cause inrushes of water of too great an extent.

This precaution, fortunately, was only of service in the case of two excavations, where it was of the greatest assistance. This was the case for pier No. 4, which was crossed by a small fault in the carboniferous shale, that was also shown on the geological map of the district, and was indicated perfectly by the pile-driving graphs to be described later.

In addition, this method enabled a stopping of gravel to be left in all the excavations at the feet of the piles which were driven to a slight depth in the shale, thus assisting in ensuring tightness.

The piles employed were « Terres Rouges, type III », which at the time of acquisition were the most economical.

2. *Driving the piles.*

The method of progressive driving was adopted. The piles were first of all set up and fitted into each other. They were sunk to a depth of 1 m. (3 ft. 3 3/8 in.) only and in this way the oval was mark-

ed out before the actual piledriving was begun.

The piles were 10 to 12 m. (32 ft. 9 in. to 39 ft. 4 in.) long, and for the purpose of setting them up and fitting them together, a gauge or templet was erected at a height of about 4 m. (13 ft. 4 1/2 in.) (fig. 4). The pile-driver was shifted about on this scaffolding. The elevated position of the working floor facilitated the fitting together of the piles and allowed a lower, and hence handier, pile-driver to be used.

Once the piles had been set up they were driven in by strokes of 1 to 1.50 m. (3 ft. 3 3/8 in. to 4 ft. 11 in.) maximum. The pile-driver thus went 6 or 7 times round the gauge before the piles were driven home.

If the piles are driven directly home, one after another, they very easily become disengaged from one another, since at the beginning they are guided over too short a length. The method adopted, although obviously longer, obviated this disadvantage.

The operation of pile-driving was followed very closely, pile by pile, and a pile-driving graph was drawn up, an extract from which is given elsewhere (fig. 5).

This graph shows distinctly all the anomalies in the sinking of the piles, and allowed the sinking of certain stubborn piles to be watched more particularly, so that, if necessary, they could be stopped and the boulders jammed beneath their feet could be removed if they had not already been sunk too far.

In addition, this was the only available means of ascertaining when the piles had been driven to the bottom. In point of fact, owing to the retardation of sinking in unit time (one minute) for a definite timing of the hammer strokes, the graph showed a marked change in direction. When the tangent to the pile-driving curve approached the horizontal, it was a sign that the end of the pile-driving operation was near, and it was then merely necessary to watch the sinking very attentively, when it could be stopped in time to be sure of having reached the shale, without damaging the head and foot of the pile.

As regards the first excavation, it was obviously doubtful whether the shale had been penetrated, but this doubt was removed as soon as the excavation was cleared. It could be seen distinctly that some piles had entered the shale. By referring to the graph, their speed of sinking at the end of pile-driving was deduced.

Subsequently, all the piles were driven in until this speed was reached, showing that they had arrived in the shale formation.

This method gave complete satisfaction. The shale was always reached, and the piles, being well cared for in this way, retained a high marketable value, which enabled them to be sold readily and for a good price after they had been used three or four times.

Each time they were used again, the piles were inspected, the inspection consisting in passing a gauge about 1 m. (3 ft. 3 3/8 in.) long in their joints, the grooves being closed by blows with a sledge at the places where they were too wide.

There were only four instances of the piles becoming disengaged to any serious extent. It must be admitted, however, that this was inevitable, since the piles had encountered large sandstone boulders which had caused considerable damage to them (fig. 6).

3. *Excavating and shoring.*

Once the piles were driven in, exca-

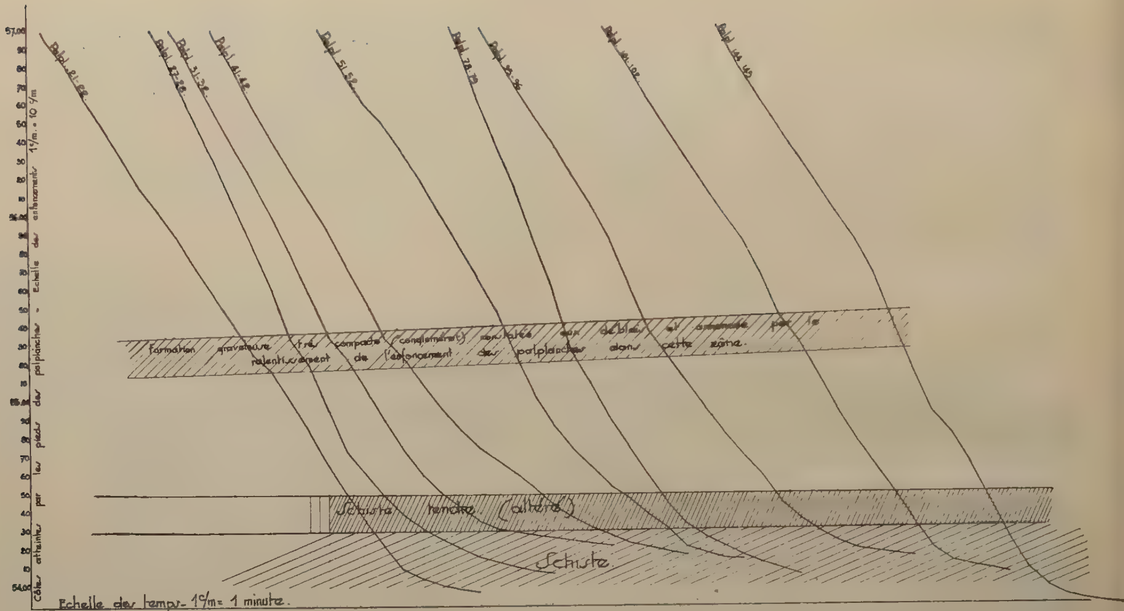


Fig. 5. — Extract from the pile-driving graph for pier No. 3.

Explanation of French terms: Cotes atteintes etc. = Levels attained by the feet of the sheet piles. — Echelle des enfoncements etc. = Scal sinking : 1 cm. = 10 cm. — Echelle des temps etc. = Scale of time : 1 cm. = 1 minute. — Format on graveleuse etc. — Gravelly format very compact (conglomerate) found on excavating and indicated by a reduction in the rate of sinking of the sheet piles in this zone. — Pa = Sheet pile. — Schiste = Shale. — Schiste tendre = Soft shale (broken).

vating was begun. This was carried out by means of grabs of the « Barnard » type known as « halftine », having a capacity of 1 1/4 m³ (1.63 cubic yard). The grab was lifted and lowered by the electric winch of a steel derrick erected on a wooden staging adapted to move on wheels above the excavation (fig. 7). The winch was capable of lifting 5 tons at a speed of 1 m. (3 ft. 3 3/8 in.) per second.

The piles were supported by hoops, each formed of two 52-kgr. (104 lb. per yard) Belgian State rails, bent on the spot. Thus, there was no prop across the excavation, and hence a space of 250 m² (2 690 square feet) was left entirely free, in which it was easy to work, both as regards the excavation of the earth and concreting (fig. 8).

The distribution of the hoops, the number of which varied from two to

Fig. 6.

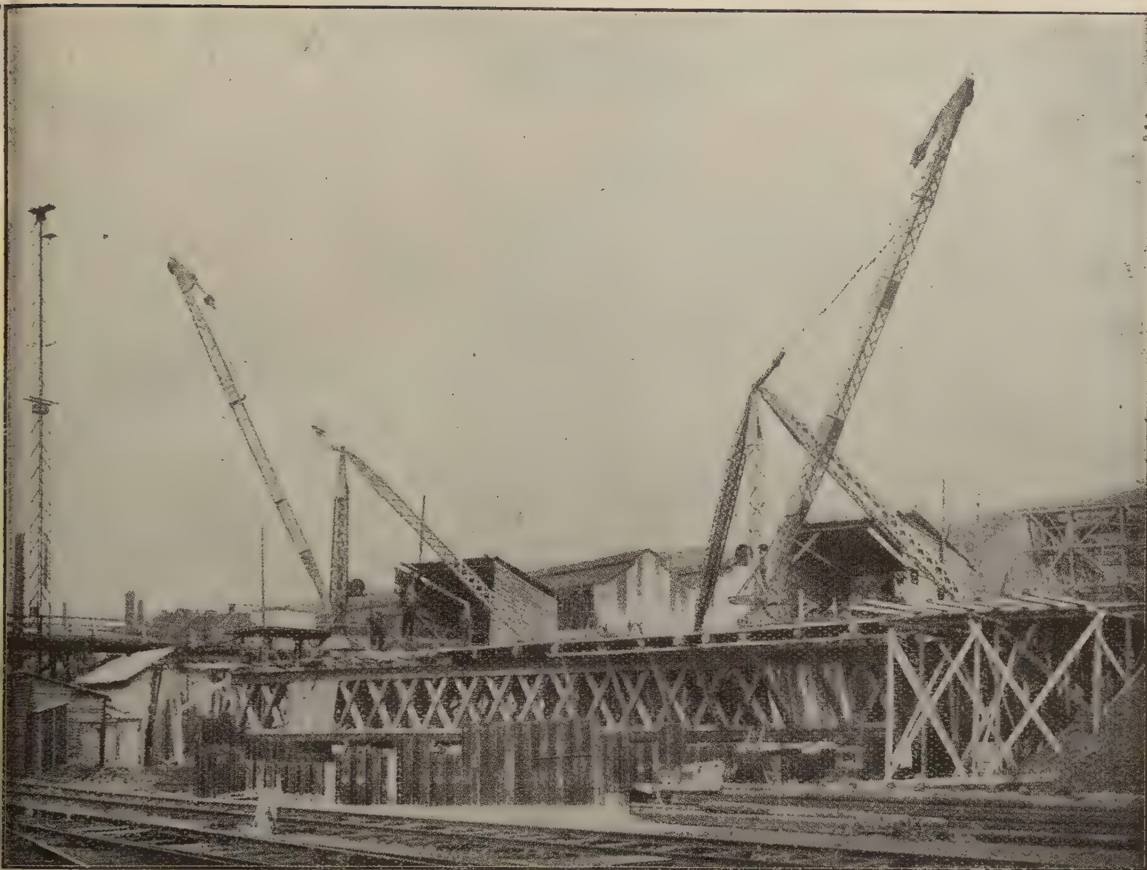


Fig. 7.

three for the ordinary excavations, was determined by considerations of the thrust exerted on the piles by the ground and water.

The hoops were suspended by means of iron hooks, the first hoop from the heads of the piles, and the following hoops from the hoop preceding them. This arrangement was only useful at the time the hoops were being placed in position. Afterwards, it only formed a double security, since the hoops were then prevented from slipping by the friction caused by the pressure.

In addition, the hoops were stayed against each other by means of vertical props intended to prevent them from buckling in case there was a tendency for movements to be produced.

The piles and hoops were tightened together by means of oak wedges about 10 cm. (4 inches) thick, spaced at regular intervals round the circumference of the excavation. The advantage of this method was that, in case of a slight inrush of water, it allowed new piles to be slipped in between the hoops and the old piles, the new piles fitting in with

Fig. 8.

the plan of the old piles. Additional support was thus not required for the new piles, it being merely necessary to replace the original wedges by thinner ones.

The design of the lining for pier No. 2, situated in the slope of the railway embankment of the Nord Belge Railway was particularly intricate. The excavations actually went to a depth of 13 m. (42 ft. 8 in.) below the level of the track, and the piles were only 1.75 m. (5 ft. 9 in.) away from it. Heavy train traffic, such as the Liége-Paris express had to be maintained.

The problem was solved by using four steel hoops and one ferro-concrete hoop, there being no more steel hoops available at that time. It was also necessary to place the hoops obliquely so as to ensure satisfactory distribution of the thrusts, the level of the ground being much

higher on the track side (embankment slope) than on the opposite side.

The work was crowned with success. The removal of the earth, the concreting and the filling in were effected without the tracks sinking more than 5 cm. (2 inches), the masonry of the railway platform wall twisted a few centimetres only, without, however, showing any signs of cracks.

It has been thought that it would be of interest to our young colleagues to give an outline of the method adopted in making the calculations for the lining of the excavation for this pier.

The excavation, of oval shape, had a depth, as previously stated, of 13 m. (42 ft. 8 in.) opposite the passenger platform of the Sclessin halt, 1.75 m. (5 ft. 9 in.) from the outer rail of the Liége-Namur line.

At this point, the line runs on an embankment. At the foot of the slope alongside the station approach, the excavation was only 10 m. (32 ft. 9 in.) deep, the platform being 3 m. (10 feet) higher than the roadway running alongside.

To this lack of symmetry in the forces acting upon the wall of piles subjected to the pressure of the ground, was added the load, with impact, of the adjacent tracks on which the traffic was still maintained.

It was necessary, therefore, to stiffen this wall, so that the excavation would not become more oval through the shortening of the minor axis with corresponding lengthening of the major axis, the perimeter remaining constant, the classical case of a tube subjected to external pressure, collapsing as soon as the mean fibres deviate from the circular shape.

In the final analysis, it was a question of ascertaining that the hoops or stiffening frames, judiciously spaced in the vertical direction, were squared sufficiently to prevent warping of the wall of piles.

These hoops had to submit to active pressures from the ground in certain zones and to passive pressures on the wall in the vicinity of the railway.

This led to a determination of the pressures on the wall in the vicinity of the railway.

These pressures are as follow :

1. Pressure of the ground above the water level.

This is given by the formula deduced by Rankine for the case of sand, neglecting the cohesion of the mass of earth. This formula was evidently indicated, in view of the fact that a gravel formation was present.

Active pressure :

$$p_1 = w \times h \times \tan^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right)$$

h = depth below the surface at which the pressure p is exerted.

w = density of the ground, say 1.8 t. per m^3 (1.35 Engl. ton per cubic yard).

φ = angle of repose (angle of friction) of the natural slope, say 37°, whence $p_1 = 0.45\ h$.

2. Active pressure of the ground and pressure of the water below the water level.

The active pressure for immersed ground is given by the preceding formula, in which, however, w is the weight of a cubic metre diminished by the weight of the water displaced, *i. e.*, w is practically equal to 1. For the water, it is the hydrostatic pressure.

The total pressure is thus

$$p = h \times 1 \times \tan^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right) + h = 1.25\ h.$$

This pressure is therefore greater than that of the dry ground by

$$p_2 = p - p_1 = 1.25\,h - 0.45\,h = 0.8\,h.$$

3. Horizontal pressure p_3 due to the passage of trains.

The two main tracks are assumed to be loaded by 22..5-t. (22.1 Engl. tons) axles, spaced at intervals of 1.50 m. (4 ft. 11 in.) *i. e.*

$$\frac{22.5}{1.5 \times 2} = 7.5 \text{ t. per linear metre (2 25}$$

Engl. tons per linear foot) of rail.

If the ground were perfectly elastic, the pressure on a vertical wall would be determined by Boussinesq's law.

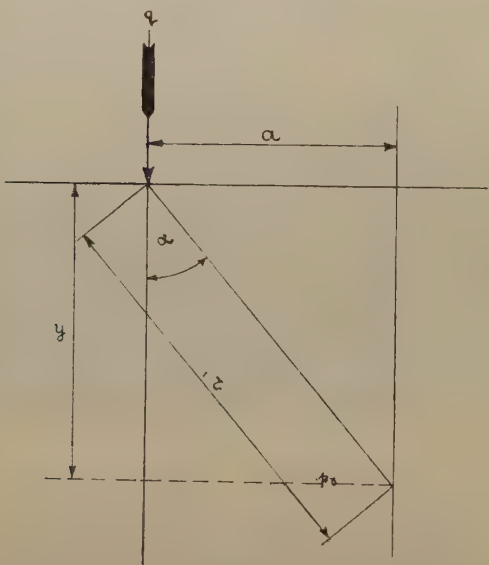


Fig. 9.

For a load q per metre of rail acting on a mass limited by a horizontal plane and for a vertical wall at a distance of a from the line of load (fig. 9), this law is written

$$p_3 = \frac{2}{\pi}\frac{q}{r}\cos\alpha\sin^2\alpha = \frac{2}{\pi}\frac{q}{a}\cos\alpha\sin^3\alpha$$

r being the distance of the vertical element to the line of load and α the angle made with the vertical by the corresponding radius vector.

If y is the depth of the element :

$$\tan\alpha = \frac{a}{y}\,;\ \cos\alpha = y\,(a^2 + y^2)^{-\frac{1}{2}}\,;$$

$$\sin^3\alpha = a^3\,(a^2 + y^2)^{-\frac{3}{2}}$$

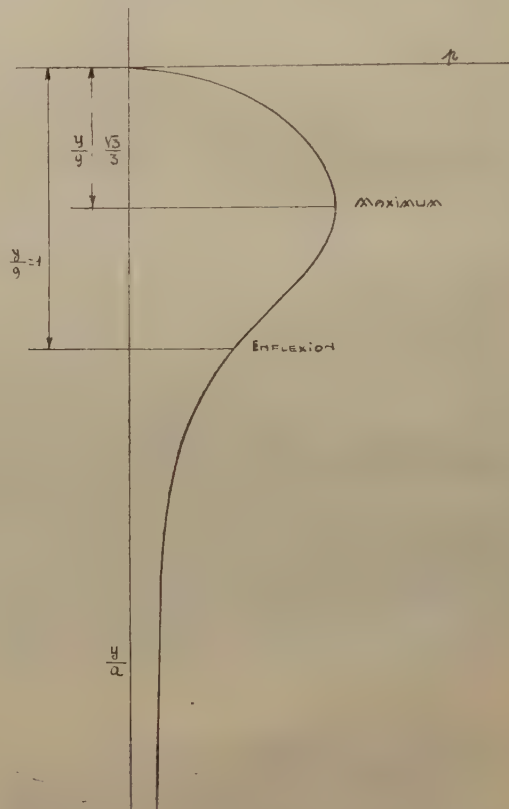


Fig. 10.

whence, for the horizontal component p_3 of the pressure,

$$p_3 = \frac{2}{\pi}\frac{q}{a}\,y\,(a^2 + y^2) - \frac{1}{2}$$

$$\times\, a^3\,(a^2 + y^2)^{-\frac{3}{2}} = \frac{2}{\pi}\,qy\,\frac{a^2}{(a^2 + y^2)^2}$$

For memory, the vertical component is equal to

$$\frac{2}{\pi} q \frac{y^3}{(a^2 + y^2)^2}$$

As a guide, p_3 is a continuous function of y with a maximum for $y = \frac{a\sqrt{3}}{3}$ and a point of inflection for $y = a$.

The curve in figure 10 indicates the form of the law $p =$ function of $\frac{y}{a}$ and shows that the pressure diminishes very rapidly as the depth increases.

For the four rails, the distances a are: 1.75 m., 3.25 m., 5.35 m., 6.85 m. (5 ft. 9 in., 10 ft. 8 in., 17 ft. 6 5/8 in., 22 ft. 5 11/16 in.), whence the following table is deduced :

	$y =$ 1	2	4	8	16
For $a = 1.75$	$p_3 = 0.89$	0.59	0.16	0.03	0.003
For $a = 3.25$	$p_3 = 0.38$	0.48	0.29	0.08	1.02
For $a = 5.35$	$p_3 = 0.16$	0.26	0.28	0.13	0.03
For $a = 6.85$	$p_3 = 0.10$	0.18	0.23	0.15	0.04
	$\Sigma p_3 = 1.53$	1.51	0.96	0.39	0.09

It is easy to see that this law assumes elastic stresses which, in the neighbourhood of the free surface, make with the normal to the element of area angles greater than the angle

$$\varphi = \left(\frac{\text{horizontal component}}{\text{vertical component}} = \frac{a^2}{y^2}\right)$$

In the neighbourhood of the surface, the passive pressure of the ground is an absolute limit which cannot be exceeded; the Boussinesq pressure cannot thus be realised and the pressures given are, for the entire upper zone, maxima which cannot be attained.

On the contrary, on penetrating deeper and deeper into the mass the pressures and the Boussinesq thrusts as was seen in the above, diminish very rapidly owing to the radial direction of the isostatics.

The most unfavourable assumption which may be made as regards the pressures at a great depth is, on the contrary, that the group of isostatics is composed of parallel straight lines, and that the horizontal pressures are maintained.

Under these conditions, the pressure in all points would be

$$\frac{22.5}{\text{relating to one axle}} = \frac{22.5}{1.5 \times 3.6} = 4.16 \text{ t. per m}^2 \text{ (0.380 Engl. ton per sq. foot)}$$

$$\text{giving a thrust of } 4.16 \tan^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right) = 4.16 \tan^2\left(45^\circ - \frac{37^\circ}{2}\right) = 1.04 \text{ t. per m}^2$$

(0.095 Engl. ton per sq. foot)

The pressure diagram in figure 11 shows that, beyond 4.20 m. (13 ft. 9 11/32 in.), this thrust exceeds the Boussinesq thrust. It is therefore logical to consider the lining of the excavation by adopting an enveloping curve for the pressures determined for the first 4.20 m. by the Boussinesq thrust and for the lower part by the pressure of the parallel isostatics.

In order to allow for the impact and vibrations, the pressures relating to the trains were doubled.

By the aid of the planimeter, by graphical integration or analytically, the total pressure of wall is found to be 92 t. per metre (8.4 Engl. tons per sq. foot).

In considering the lining, it is necessary and sufficient to know the maximum thrusts exerted on the generatrix subjected to maximum load. It is therefore necessary to seek the maximum load conditions of the surfaces of the embankment.

As regards the pressure of the ground itself, it was assumed that all the surface of the ground was situated at the level of the railway platform. Actually, this height of ground only prevailed over a small area.

As regards the additional pressure due to water, it was assumed that the normal water level was 7.60 m. (24 ft. 11 in.) above the bottom of the excavation.

The additional load due to trains was assumed to be given by an infinite series of 22.5-t. (22.1 Engl. tons) axles, spaced at intervals of 1.50 m. (4 ft. 11 in.).

These conditions thus lead positively to the maximum thrust.

For calculating the hoops, it may be assumed that the stresses in them follow the funicular diagram corresponding to the mean fibre, the cross-sections being compressed.

The thrusts of the ground at the side of the road parallel to the foot of the embankment ought strictly to be in equilibrium with the thrust determined for the side of the tracks and shown in the diagram (fig. 11).

It should be noted that the radii of curvature of the hoops are the same in both these regions.

The mass of the ground is in equilibrium under the action of the horizontal forces comprised between the two values given below, totalling the pressure of the water and that of the ground.

$$h + 1 \times h \tan^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right) = 1.25\,h$$

and

$$h + 1 \times h \tan^2\left(\frac{\pi}{4} + \frac{\varphi}{2}\right) = 5\,h.$$

The first value, the minimum limit (active thrust), gives a total thrust of :

$$p = 1.25\frac{h^2}{2} = 1.25 \times \frac{100}{2} = 62\text{ t. }5$$

(5.7 Engl. tons per sq. foot).

The second value, maximum limit (passive thrust), gives a total thrust of :

$$p = 5\frac{h^2}{2} = \frac{5 \times 100}{2} = 250\text{ t.}$$

(22.8 Engl. tons per sq. foot).

The force required being 92 t. (8.4 Engl. tons per sq. foot) (resultant calculated previously), the equilibrium is very satisfactory.

The piles were considered in the calculations as continuous beams supported on the hoops (the end or the point being assumed free), after having determined a judicious distribution of the hoops with the aid of the diagram of pressures.

As regards the hoops, the load per metre of length being p and the radius of curvature ρ, the classical theory of bent members gives as compressive stress $p\,\rho$.

Under these conditions, with the four hoops arranged as shown in figure 11, the maximum load on the piles is 13.75 kgr. per mm² (8.73 Engl. tons per sq. inch), and that on the hoops is 21.5 kgr. per mm² (13.65 Engl. tons per sq. inch).

This method of verification, based on the assumption that the hoops were put under compression alone, may appear rather simple to the strict mathematician.

In what follows we give a solution of

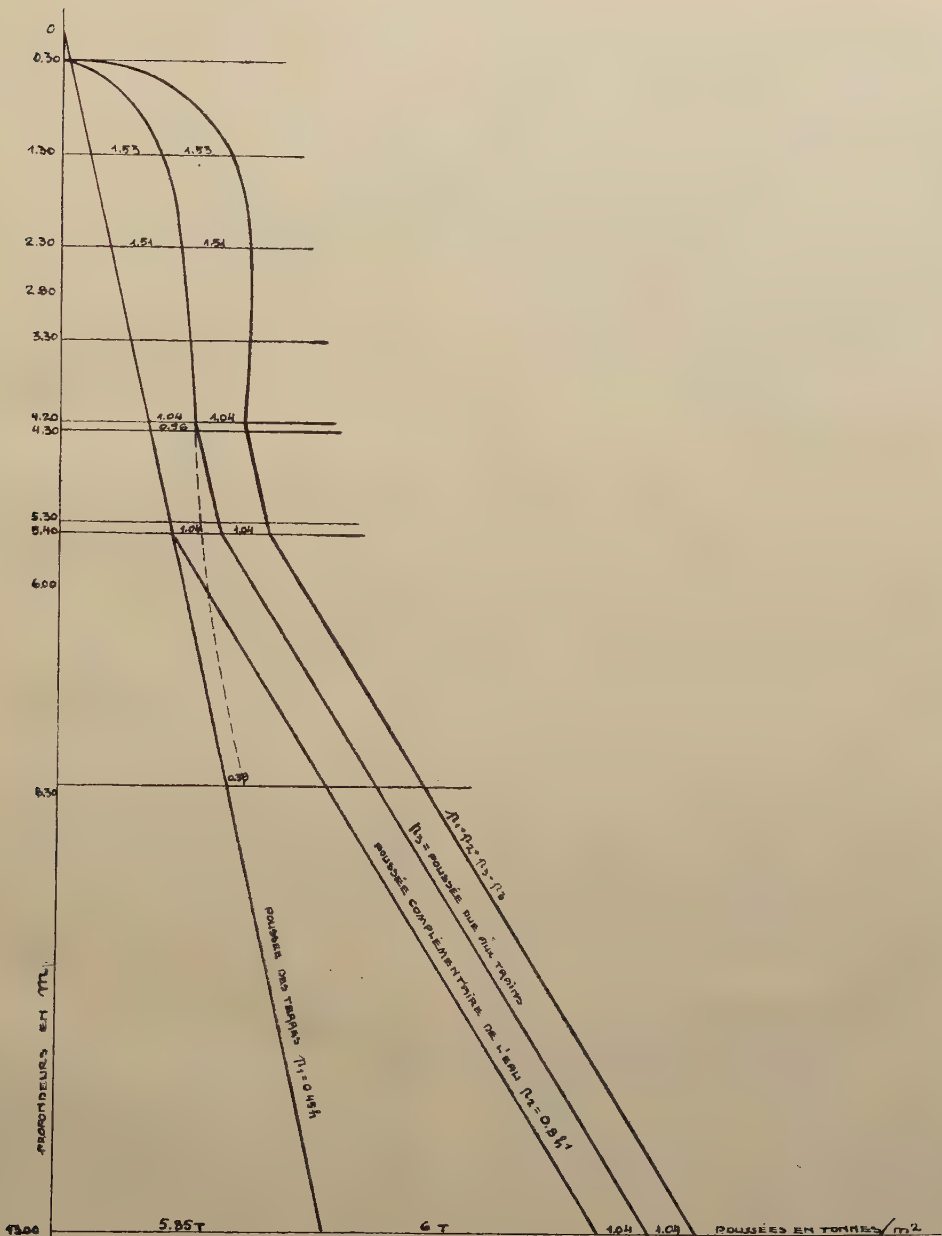


Fig. 11. — Diagram showing the pressures in metric tons per square metre on a vertical wall, 1.75 m. (5 ft. 9 in.) from the rail.

Explanation of French terms: Poussée = Pressure or thust. — Poussée complémentaire de l'eau = Supplementary pressure of the water. = Poussée des terres etc. = Pressure of the ground (metric tons per square metre). — Poussée due aux trains = Pressure due to trains. — *Note* : Ordinates = Depths in metres.

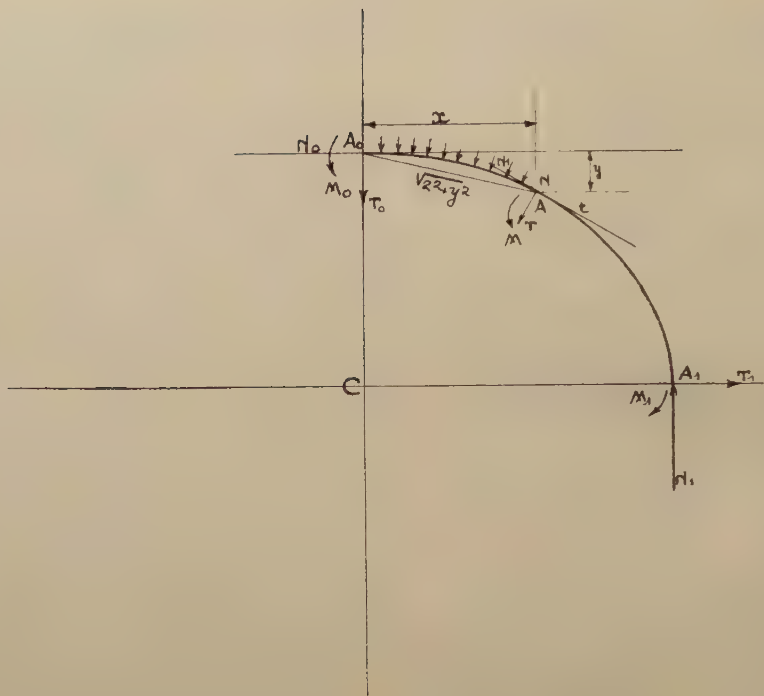


Fig. 12.

the problem based on the theory of molecular work, adapted to give the distribution of the bending moments, and the shearing and axial stresses in the stiffening rings.

Assuming a hoop of oval or elliptical shape, subjected to the action of pressures p per metre, uniformly distributed and normal to the mean fibre (fig. 12),

Let the quarter of the oval or ellipse be isolated; for reasons of symmetry, we have

$$T_0 = T_1 = 0.$$

N_0 and N_1 are determined easily from statics.

Let M be the moment at any point A in the curve having the coordinates x and y. We have

$$M = M_0 - N_0 y + p \times A_0A \times \frac{A_0A}{2}$$

in which expression M_0 is the only unknown.

The arc A_0 A_1 being fully related to an auxiliary moment m, in as much as the relations A, and A_1 do not allow any rotation owing to symmetry, we may write:

$$\frac{dT}{dm} = 0$$

the auxiliary moments m and $-m$ being applied, respectively, at A_0 and A_1.

On the other hand N and T are independent of m, whence

$$\int_0^{s_1 = \text{arc } A_0A_1} M \frac{dM}{dm} ds = 0$$

Owing to the addition of the system, statically equal to zero (m, $-m$), and the external stressing forces, the moment M is equal to :

$$M_0 + m - N_0 y + p \times \frac{\overline{A_0A}^2}{2}$$

whence

$$\frac{dM}{dm} = I$$

Putting $m = 0$ after derivation, the inertia of the hoop being constant, we obtain :

$$\int_0^{s_1} M_0 ds - \int_0^{s_1} N_0 y ds + \int_0^{s_1} \frac{1}{2} p(x^2 + y^2) ds = 0$$

which equation will give us M_0.

This is, after all, a justifiable application of the theory of minimum work.

The simplest method of determining the integrals is the graphical method, unless the equation of the curve allows of integration by the usual methods.

The axial stress at any point A is given by the expression $(N_0 - py) \cos t + px \sin t$.

$$(N_0 - py) \cos t + px \sin t.$$

Thus, the stressing of a stiffening hoop is determined strictly for the general case.

In order to allow an economic lining to be examined in the case when the formation is clay instead of gravel, we shall give, by way of indication, the method we should have adopted. This method utilises the results obtained by the English engineer Bell for different kinds of clay.

It is known that the particles of the surface of a heap tend to slip under the effect of the tangential component of gravity. If, despite their mobility, their equilibrium is not disturbed, it is because the superficial particles are held through friction by the particles lying immediately beneath them.

Friction alone is insufficient, however, to explain all the observed facts. The coefficient of friction would in fact have to be infinite to justify the perpendicular appearance of some banks of clay.

It must be admitted, therefore, that clay, dry or slightly moist, to a certain degree possesses the cohesion of solids, one of the characteristics of which is resistance to slip.

This is, after all, the assumption made by Coulomb, namely that the force which opposes the mutual slipping of two portions of a mass of earth on a common plane is composed of two parts :

1. Friction, proportional to the normal pressure as when two bodies slide one upon the other.

2. Cohesion, independent of the normal pressure, and having a definite value per unit of area and hence proportional to the surface of separation.

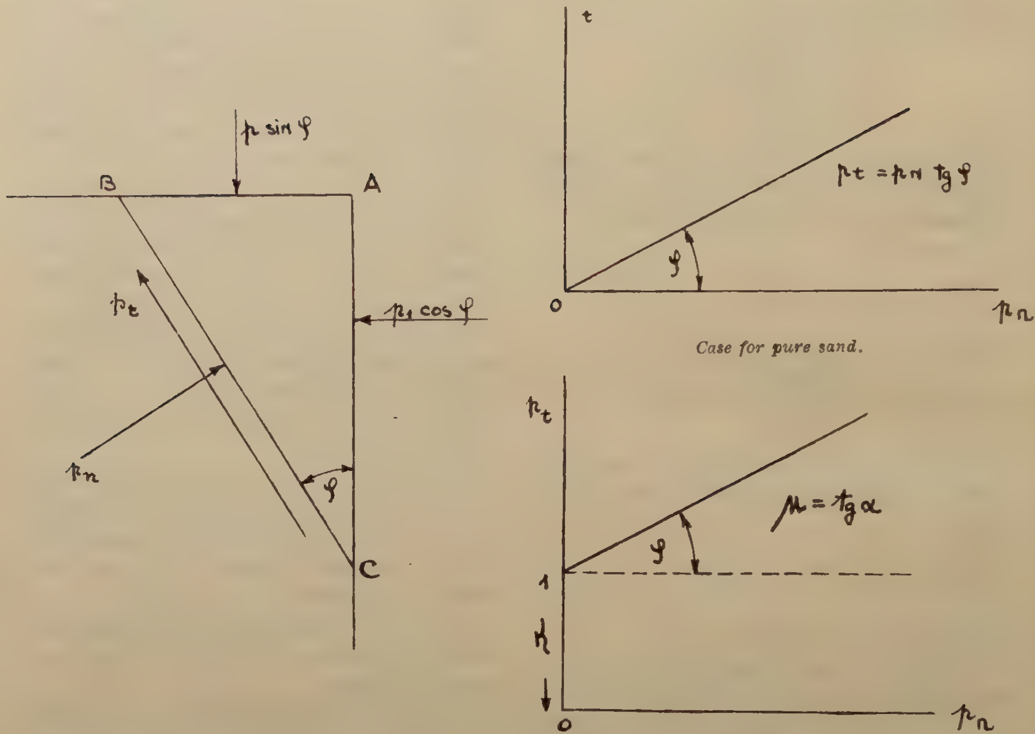
In point of fact, it has been shown experimentally that the resistance to shear of clay is represented by the following formula :

$$p_t = k + \mu p_n$$

where p_t = shearing stress,
and p_n = normal compression stress.

Starting with this formula for the resistance to shear, the classical study of the equilibrium of a triangular prism of clay, of length equal to unity, leads to the following formula for the active thrust at a depth h (fig. 13) :

$$p = wh \tan^2\left(\frac{\pi}{4} - \frac{\alpha}{2}\right) - 2k \tan\left(\frac{\pi}{4} - \frac{\alpha}{2}\right)$$



Case for pure sand.

Case for clay.

Fig. 13.

the passive thrust being equal to

$$wh \tan^2\left(\frac{\pi}{4}+\frac{\alpha}{2}\right)+2k\tan\left(\frac{\pi}{4}+\frac{\alpha}{2}\right)$$

It is easy to see that by making $\alpha = \varphi$ and $k=0$ (zero cohesion) the formulae deduced by Rankine are obtained.

The English Engineer Bell has performed numerous experiments on different kinds of clay and has obtained the following results :

Very soft clay	$k = 2.2$ t. per m²	$\alpha = 0°$
Soft clay	$k = 3.3$ t. per m²	$\alpha = 3°$
Comparatively hard clay	$k = 5.5$ t. per m²	$\alpha = 5°$
Hard clay	$k = 7.7$ t. per m²	$\alpha = 7°$
Very hard clay	$k = 17.6$ t. per m²	$\alpha = 16°$

4. *Drainage.*

The inrushes of water were very variable in extent from one excavation to another.

We consider it useful to mention one point, which although insignificant on the face of it, was not without its importance. As soon as water started to come in below the piles or through the gravel stopping, and once the bottom of the excavation had been reached and everything was ready for concreting, no attempt was made to stop up the place where the water was coming in. The water was led towards the strainers of the pumps by any suitable means : earthenware pipes or, for reasons of econo-

my, a simple open channel. It was then possible to concrete all round the drain without fear of the concrete being washed away, and in this way, the bottom of the excavation was covered with concrete with the exception of the drain. One or two days later, the concrete having hardened, the entrance to the drain was blocked by a few sacks containing dry concrete, and after having removed the water in the drain, it was also concreted.

The water from the spring then made its way to the sump by flowing round the concrete previously put down, without damaging the work.

Proceeding otherwise, the spring, partly blocked up in any one place, seeks an outlet elsewhere and unavoidably finds one. The result is that the water gradually spreads, of course in small quantities, over the entire surface of the bottom, which is detrimental to satisfactory concreting.

The water was pumped out by means of electric suction pumps having flexible couplings, the pumps being 150 mm. (6 inches) in diameter. They were obtained from the Heinricks works and were provided with two rotors, an ordinary one having flanges and blades was used in pumping out the clear water while the major portion of the earth was being dug out, and the other, with three strong blades, without flanges, was used for pumping during the last part of the excavation, when the muddy water mixed with gravel and shale rubble was pumped out continuously.

The efficiency with open rotor was evidently less, by about 25 %, than that with the normal rotor, but the fact that it was possible to work without interruption largely compensated for the loss in efficiency.

The motor-pump sets were installed on movable platforms which could be raised or lowered into the excavations by hand winches. In this way, there was never more than 5 m. (16 ft. 5 in.) suction height, and the discharge was practically constant, even at considerable depths. It is a known fact that it is preferable to increase the height of delivery rather than that of suction. Experience teaches that, for ordinary yard pumps, the efficiency falls very rapidly once a suction height of 5 m. (16 ft. 5 in.) is exceeded, and becomes practically zero at 8 m. (26 ft. 3 in.).

These movable platforms would also have enabled the pumps to be saved if an excavation had been suddenly inundated.

5. *Shuttering of the end abutments.*

For the end abutments, the dimensions of which rendered the substitution by oval shaped foundations impossible without involving the purchase of special stiffening hoops and extensive and useless excavation work, it was necessary to adhere to the rectangular shape.

After examining different methods of lining, choice fell on the use of reinforced concrete frames made with « Ceberit » cement (rapid-hardening cement) so that they could be put under load at once (fig. 14).

The chief advantages were that they left very large spaces free for work (3 compartments of about 6.00 × 9.00 m. [19 ft. 8 in. × 29 ft. 6 in.]) and that their cost was economical.

When the floor had reached the required level for setting up a frame, lateral internal shuttering was arranged, the ground forming the bottom coffering. The reinforcement was placed in position and the concrete was made on the spot with the gravel and the water from the excavation.

Two similar frames were made for

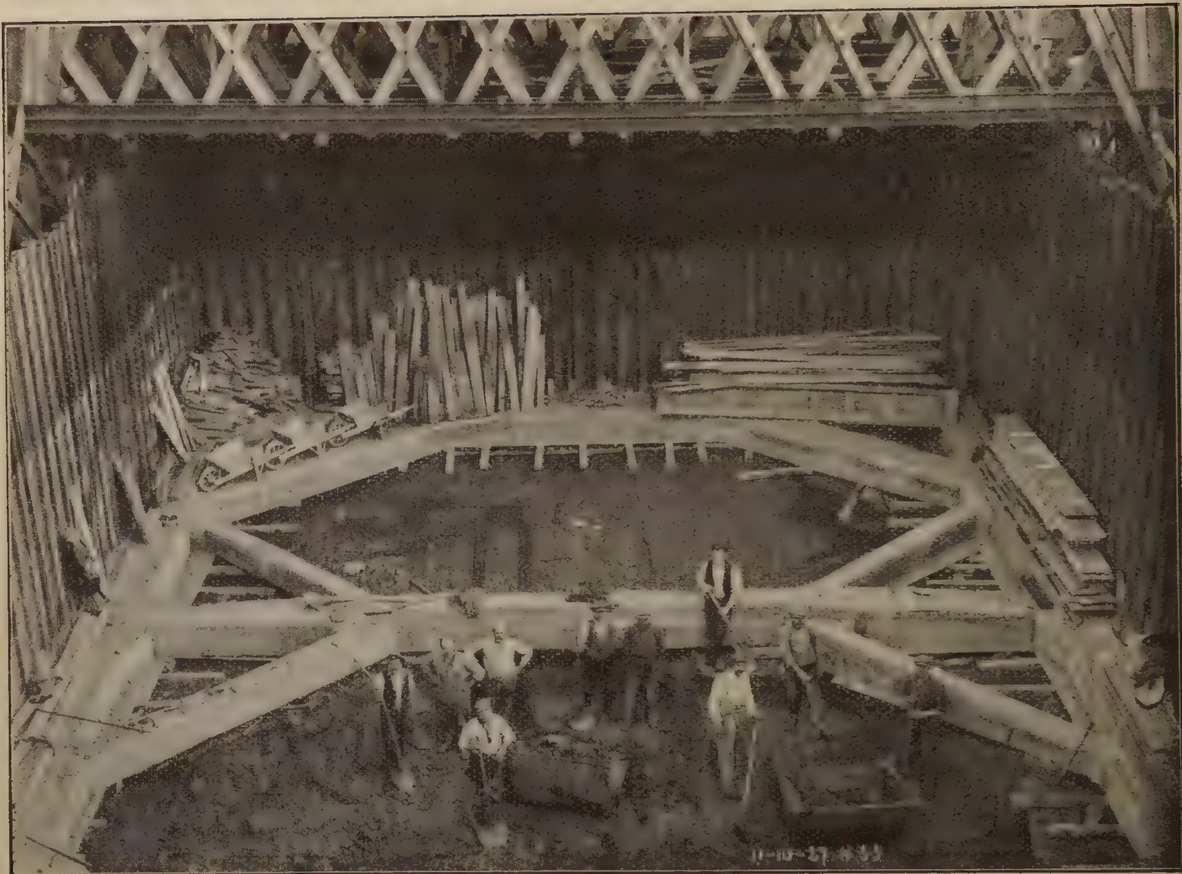


Fig. 14.

each abutment. These frames were calculated to receive both together the pressure of the ground without, however, reaching exaggerated dimensions.

Care was taken to insert between the piles and the side of the frames a sheet of tarred paper, to prevent the concrete sticking to the piles and the cement from penetrating their grooves, which would have made the subsequent withdrawal of the piles very difficult.

It should be noted that the two concrete beams, having a 13 m. (42 ft. 8 in.) span, and forming the stay, were not supported across the excavation, and had an upwardly concave shape. Thus, when they were put under load, owing to the continuation of the excavation, giving rise to lateral thrusts, and at the same time depriving the beams of their support, the neutral axis under the effect of the dead weight corresponded nearly with the axis of thrust, thus avoiding bending moments.

The piles were driven by means of MacKernan Terry or Pajot double acting

compressed air hammers. The pile drivers were No. 7, weighing about 1 200 kgr. (2 640 lb.), striking at the rate of 150 to 200 blows per minute. The compressed air was provided by two Ingersoll horizontal compressors, each delivering 14 m^3 (494 cubic feet) of compressed air at 7 kgr. per cm^2 (100 lb. per sq. inch) per minute. They were driven by 87-H. P. electric motors.

6. *Withdrawal of the piles.*

The same plant was used for withdrawing the piles, the hammers being simply turned round and provided with their withdrawing devices. After several failures with the first two excavations, the problem was solved in an effective manner by means of several contrivances, so much so that one may say that almost record figures were obtained, 23 piles, driven to a depth of 11 m. (36 ft. 1 in.) in the gravel being withdrawn in 8 hours.

In order to do this :

1. The pile driver and the steam winch, the latter being replaced occasionally by a compressed air winch, were mounted in parallel, that is to say, pressure was supplied to the pile driver and the winch at the same time. According as withdrawal became more or less difficult, either the winch winding up the rope was stopped, when all the air passed to the hammer striking at full speed, or it was the winch which absorbed all the air in winding up the rope whereupon the hammer, being insufficiently supplied with air, stopped striking.

At the beginning of the operation, once the rope had been wound on sufficiently, air was shut off from the winch for a very short time so as to cause the pile to be loosened by the repeated blows of the hammer, which was then working at full power. After loosening the pile in this way, the parallel arrangement was re-established.

2. A withdrawing sheer, 18 m. (59 feet) high was constructed of timber nailed together, easy to manipulate but strong (the 5-ton withdrawing winch with a 12-sided tackle gave a pull of 60 t. (59 Engl. tons), thus a compression of 60 t. in the uprights of the sheer) and means were contrived for displacing this sheer readily, the pull being exerted strictly in line with the piles, so as to avoid the considerable frictional forces produced in the grooves as soon as the pull is out of alignment.

The foundation concrete having been brought flush with the natural ground level, and the excavation having been filled in (the hoops were removed as the filling in proceeded), a scaffolding of 7 × 15 (2 3/4 × 6-inch) planks (standard type of the yard) was erected on the pier, the planks being connected together by clamps and bolts without nails and holes, thus leaving the timber intact after use. Four pivots, corresponding to the four centres of the oval of the piles, were arranged on this scaffolding.

The sheer turned round these fixed points, to which it was connected by a steel arm which could be used in two lengths (those of the radii of the outline of the oval).

Thus, the path described by the head of the sheer was exactly like the oval of the piles and there was strict perpendicularity.

This arrangement possessed the additional advantage of doing away with stays which it would have been practically impossible to place in the busy district near the railways and tramways.

This arrangement is shown in figure 15.

For the end (rectangular) abutments,

Fig. 15.

the sheer was orientated in two directions only and was connected to the scaffolding which, in this case, was moved as a whole on the foundation concrete forming a trackway (fig. 16).

7. *Excavations in the Meuse.*

The success of the methods of excavating the foundations on dry ground led the administration to authorise the contractors to carry on the work in the Meuse by means of dams instead of caissons.

The experience acquired with the foundations constructed on the banks had shown that the gravel formation was of a sufficiently clayey nature to prevent any considerable inrushes of water.

Besides, as previously mentioned, the sound shale was covered by a stratum of broken shale and relatively plastic shale into which the feet of the piles penetrated, thus ensuring tightness of the bottom, except for local breaks.

This time, however, it was not pos-

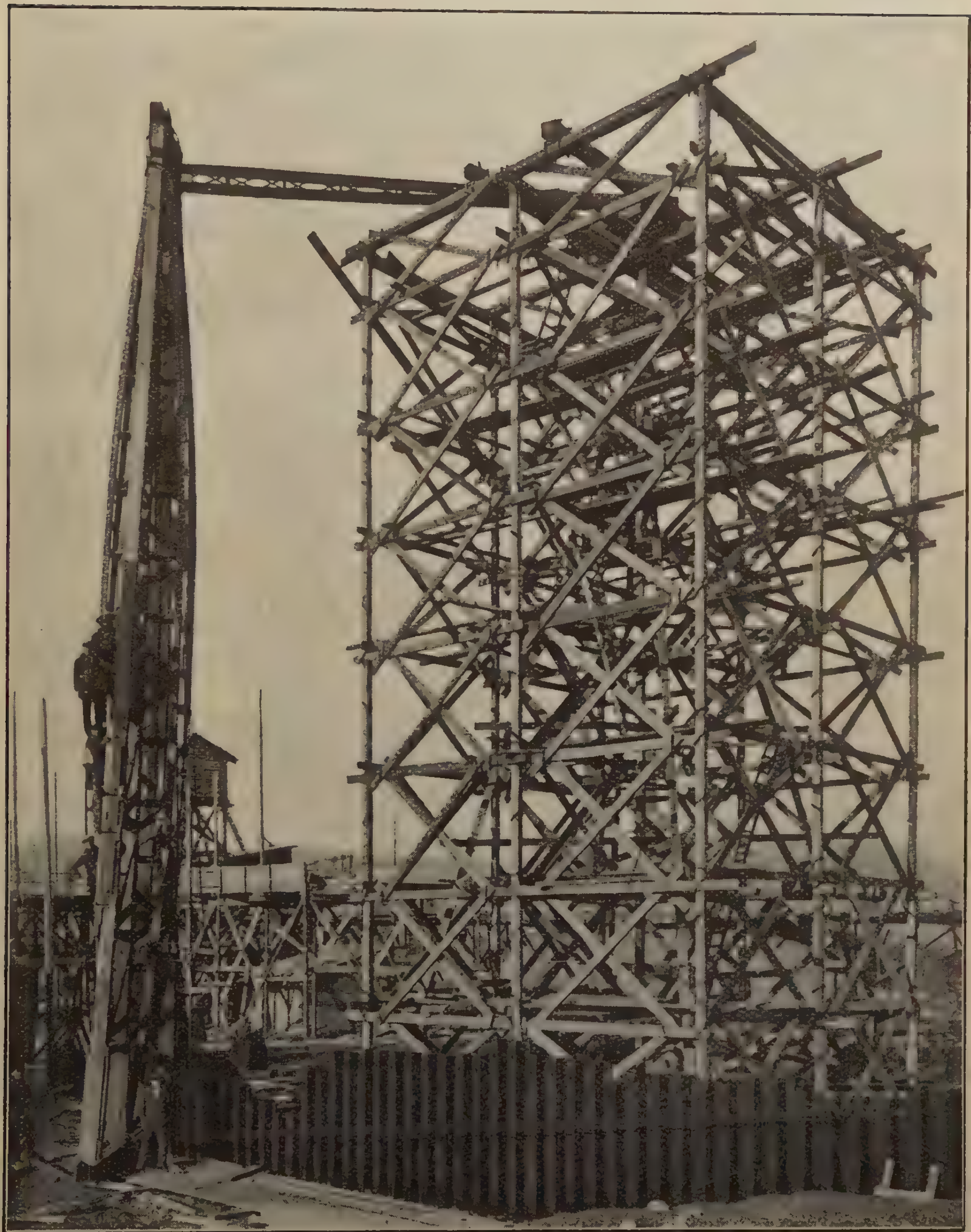


Fig. 16.

sible to rely upon the passive thrust for the stability of the cofferdam, so that the shape decided upon was that of the perfect circle. The excavation was 18.30 m. (60 feet) in diameter.

The piles were driven in gradually as in the case of the piles on the banks. The pile driver moved on a templet set up on light piers driven in the river.

Tightness was easily obtained. Driving was easy because the bed of gravel that had to be passed was thinner than in the case of the excavations on the banks and the piles, as was expected, were not damaged. As regards the portion of the piles, in the water, above the gravel, it was merely necessary to throw in gently, vertically above their grooves, fine ashes which the external pressure forced into the joints, providing immediately the desired watertightness. The fine streams of water could be seen to disappear as the ashes descended lower and lower. The water-tightness was such that at pier No. 9, a 150-mm. (6-inch) pump was alone sufficient to ensure drainage.

In order first of all to bring the piles, and later the concrete, a staging with derricks was erected round a portion of the circumference of each pier. These stagings were connected to the two banks by a footbridge leaving navigable passages 20 m. (65 ft. 7 in.) wide and 6.50 m. (21 ft. 4 in.) free height.

Figure 17 gives a clear idea of the method of construction. In addition, by comparing the two stages shown in figures 17 and 18, the rapidity obtained by means of this method will be realised. Only eight weeks have elapsed between the two stages shown.

8. *Concreting.*

The concreting of the foundations offers nothing striking. The division into steps of about one metre deep should be mentioned, in which sections of circles of constant radius were utilised. This method only requires two sets of lagging panels curved according to a mean radius, enabling all the foundations to be lagged economically.

Figure 19 shows a plan and longitudinal section of the foundations of pier No. 10.

III. — Erection.

1. Piers.

The erection of the piers offered no difficulties other than those inherent to any structure of considerable height which has to be erected on a restricted area.

One point, however, deserves mention. This is the adjustment of the bearings of the hinges. It was obsviously necessary that these bearings would have to be placed in an exact manner. The hinge at the foot of an arch is formed of a series of ten bearings adjoining the arch, and ten bearings adjoining the pier, ten hinges being interposed between them. Each of the bearings weighs 1 350 kgr. (2 970 lb.). One can appreciate, therefore, the material difficulty of arranging these ten bearings, which were difficult to manipulate, so that their axes should be on one and the same single geometrical axis, this being done without any support from the concrete, which could not be run in until later when it made a sort of self-sealing arrangement.

The diagram in figure 20 shows a hinge and the means adopted for adjusting it. These consisted in suspending each bearing from adjustable tie rods, fixed in four holes intended for the reception of the anchoring bolts. The ties acted in pairs in mutually perpendicular directions.

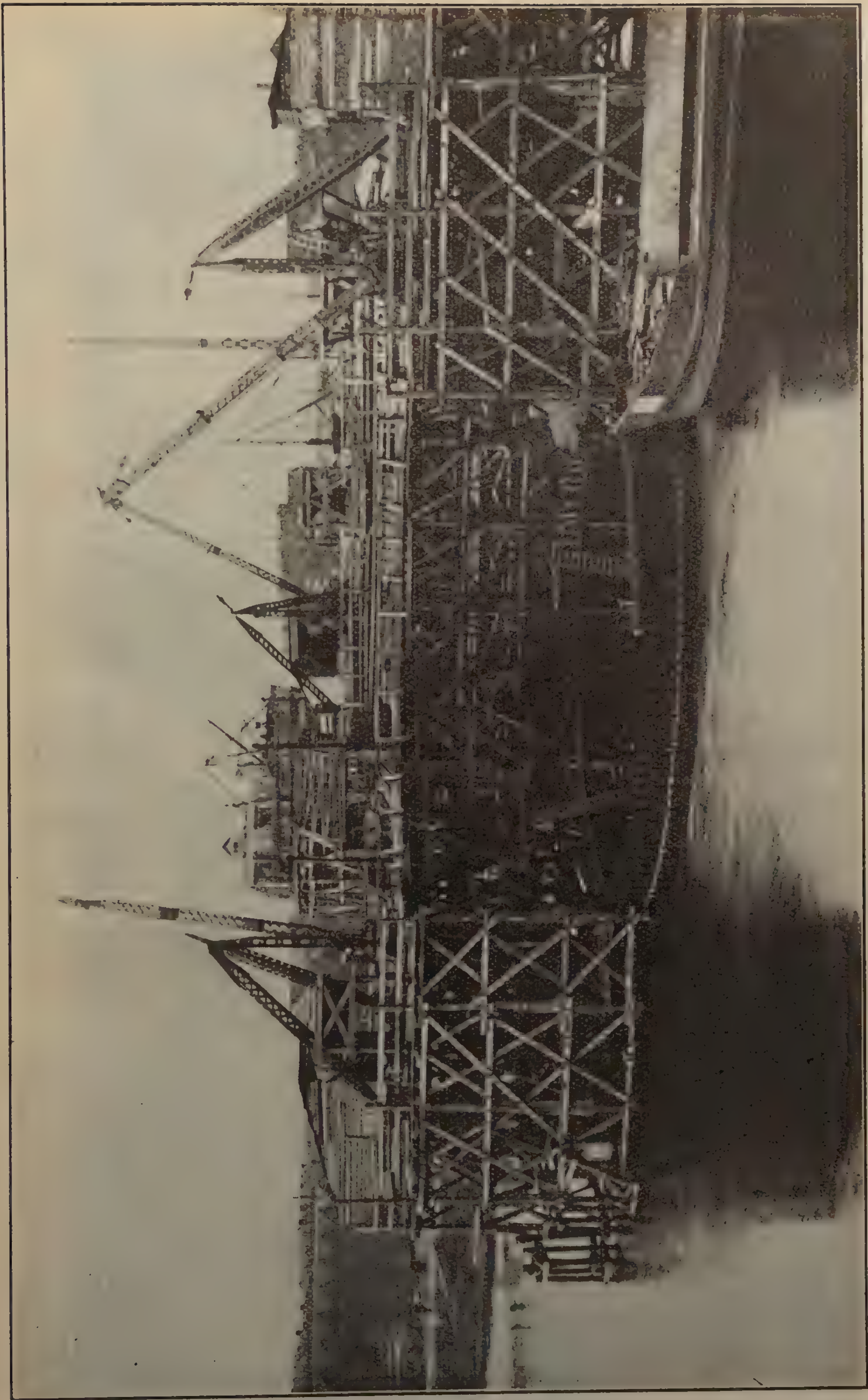
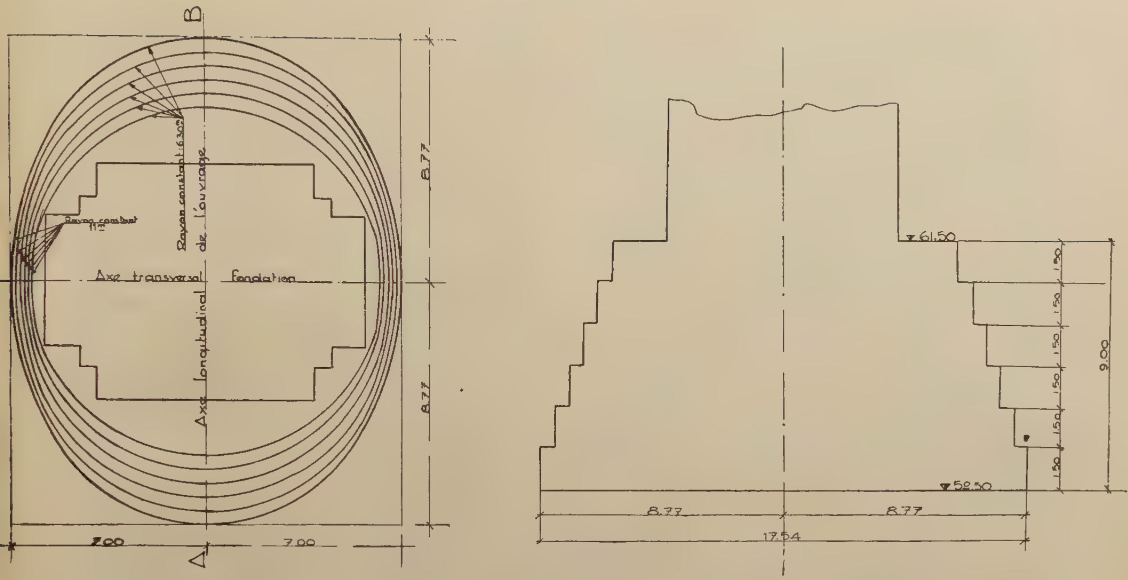


Fig. 17

Fig. 18.



Plan. *Longitudinal section along AB.*

Fig. 19. — Plan and section of the foundations for pier No. 10.

planation of French terms: Axe transversal etc. = Transverse axis of the foundation. — Coupe longitudinale etc. = Longitudinal axis of the viaduct. — Rayon constant = Equal radii.

The required mathematical position of the suspended part was readily obtained by turning the adjusting nuts.

2. Arches.

A. *Considerations affecting the centering for an arch of 61.40 m. (201 ft. 6 in.).*

a) Type of centering.

The Railway Administration had merely stipulated that the centerings should be steel and preferably with spokes (fans), and stated the limits for the stressing of the material, which were not to be exceeded. They also added that the centerings should be removed solely by means of jacks and that this should be done simultaneously for the arches or semi-arches of the same longitudinal section of the viaduct.

The Administration left the contractors free to construct the arches a half at a time, two sections, 3.75 m. (12 ft. 3 5/8 in.) wide with a joint of 0.50 m. (1 ft. 7 11/16 in.) to be filled in subsequently.

It appeared that this method might interfere with the work being completed within the stipulated time, and would risk spoiling the appearance of the intrados of the arches, since it would have been very difficult to adjust the centerings so that after their removal, the two semi-arches would be exactly flush with one another.

It was therefore decided to concrete the arches over their entire width, and consequently it was then necessary to consider the centering.

From the outset, it also appeared that it would be very difficult to erect cen-

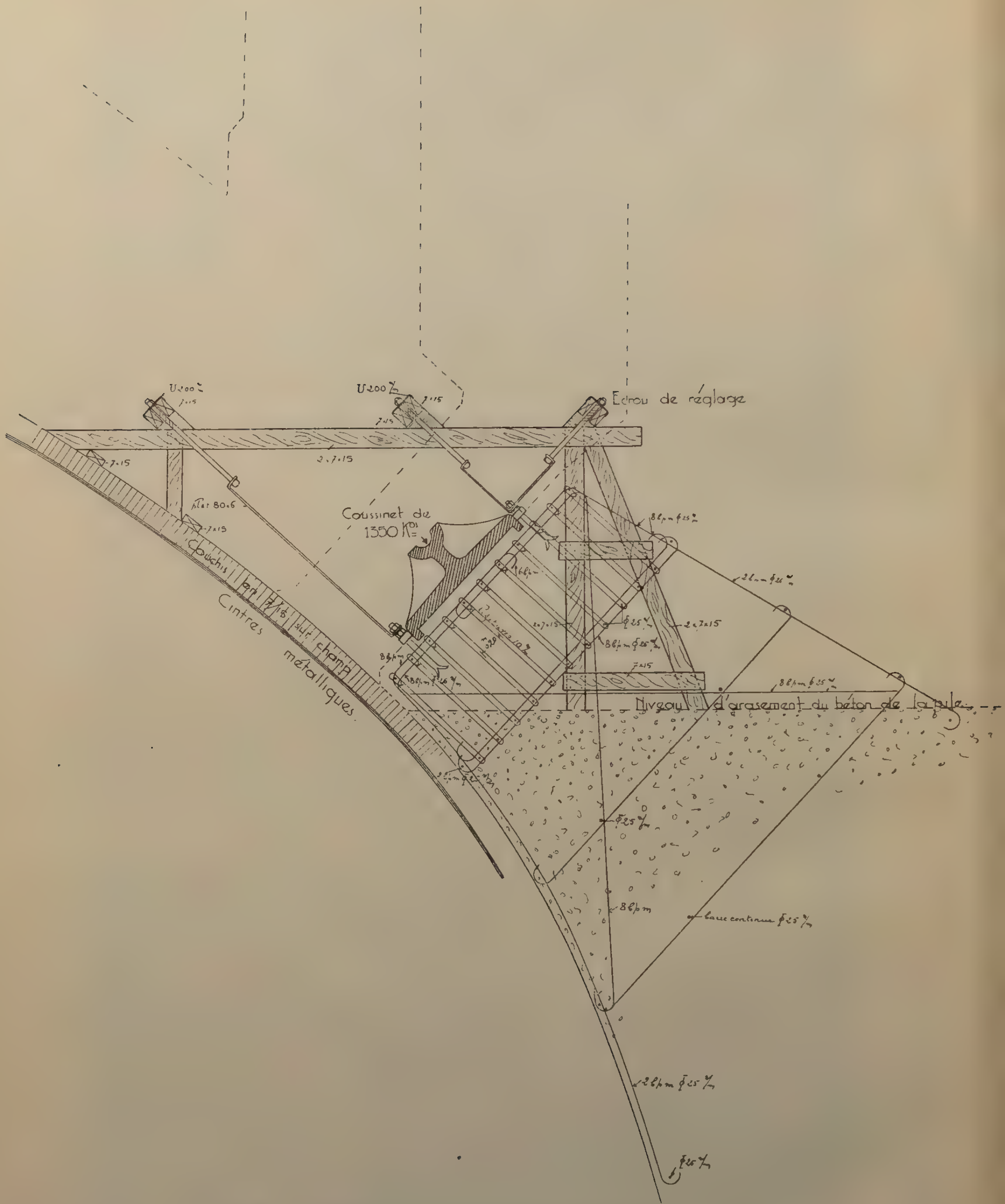


Fig. 20. — Diagram of the adjusting device for the hinge bearings.

Explanation of French terms: Cintres métalliques = Steel centerings. — Couchis etc. — Lagging of 7 × 15 (2 3/4 × 6-inch) planks on edg
Coussinet = Bearing of 1 350 kgr. (2 975 lb.). — Ecrou de réglage = Adjusting nut. — Niveau etc. — Level concrete course of pier.

terings with multiple supports, because, apart from the fact that the local conditions would not allow the supports to be arranged in the same places, even for two arches only, it would have been very expensive to proceed in this manner, seeing that it would have been necessary to make concrete beds or drive piles for each support, in view of the considerable weight of the centerings and the defective nature of the top layers of ground.

This method was still less practicable for the arches in the Meuse where wide navigable passages, unequally arranged for each of these arches (3 passages of 20 m. [65 ft. 7 in.] opening), had to be considered.

All these circumstances led the contractors to adopt the three-hinged type of centering, which afforded the following advantages :

1. The centerings were supported on hooped blocks of concrete, forming one part with the piers, resulting in a support which could not be deformed, and the strictly exact interval between which ensured the centerings being placed in position without risk. At the same time all the complications arising out of local obstacles were avoided.

2. The absence of intermediate supports, and the similarity in the design (three-hinged arches) of the centerings and the arches to be built, considerably reduced the deformation of the rigid steel supports and its consequences.

The centerings were formed of four girders in the form of three-hinged arches, spaced at a distance of 2.15 m. (7 ft. 5/8 in.) from axis to axis, and braced in both directions. Each girder was composed of two half-girders each weighing 30 t. (29.5 Engl. tons). All the centerings used for concreting simultaneously three arches, and extending from abutment pier to abutment pier, comprised eighty half-girders weighing altogether 720 t. (709 Engl. tons).

The type of girder adopted was the double lattice N — girder having box section flanges (see fig. 21).

This arrangement allows the joints to be brought near together, thus reducing the secondary bending moments in the upper ribs, due to the load of the concrete between the joints and the bending of the flange itself (this was to be adapted to the theoretical curve of the intrados of the arches as defined algebraically in the plans of the Administration).

This reduction in the distance between the joints had the additional advantage of increasing the resistance to the buckling of the flanges.

The dimensions of the parts forming the coffer section of the rails were not fixed. The webs were stiffened by means of angle-irons to resist any local buckling, which was studied by Timoshenko's method based on the equality between the work of the external forces during the warping of the plate and the molecular work of the material.

The lower flange of the girders was straight over almost the whole of its length so as to facilitate assembling the centerings on the ground or on scaffolding. At the ends it was necessary to make one portion re-entrant and curved to avoid certain fixed obstacles.

b) Support and hinge of the foot.

The foot hinge was made of a piece of cast steel 80 cm. (2 ft. 7 1/2 in.) long and 65 cm. (2 ft. 1 5/8 in.) wide, curved to a radius of 2.00 m. (6 ft. 6 3/4 in.) providing a surface of support on the

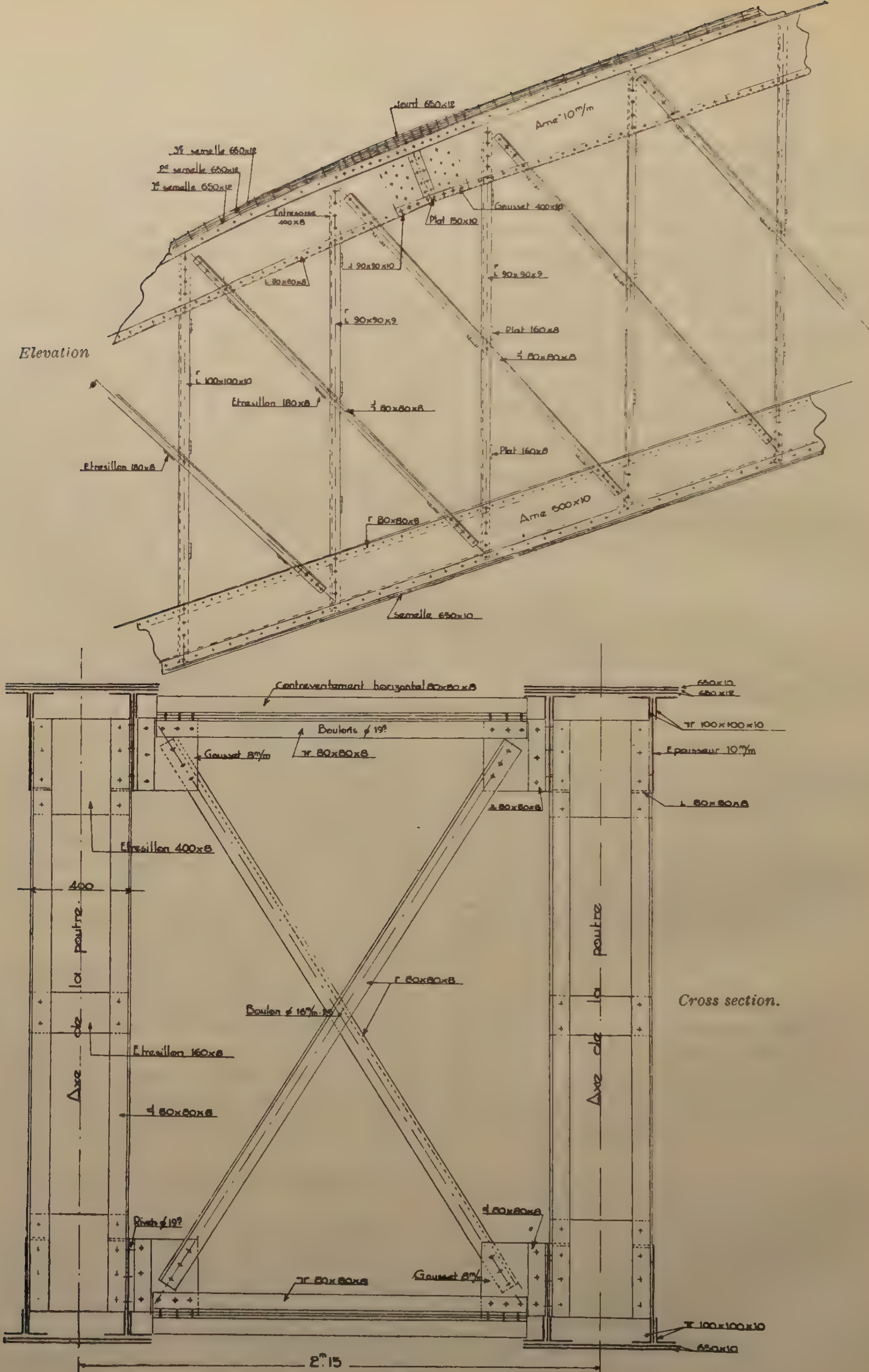


Fig. 21. — Steel centerings.

Explanation of French terms: Ame = Web. — Axe de la poutre etc. = Axis of the girder. — Boulon = Bolt. Contreventement etc. = Horizontal brace. — Entretoise = Cross-piece. — Epaisseur = Thickness. — Gousset = Gusset plate.

concrete 0.30 m. × 0.80 m. = 0.24 m² (2.58 sq. feet).

The maximum reaction calculated for the central girders was 600 t. (590 Engl. tons); the maximum load on the concrete was therefore

$$\frac{600000}{2400} = 250 \text{ kgr./cm}^2,$$

(3555 lb. per sq. inch).

which is an admissible load for hooped concrete, composed of 450 kgr. par m^3 (758 lb. per cubic yard) of Portland cement.

In these circumstances, moreover, the load decreases very rapidly, the cone of pressure extending and affecting greater and greater sections. No cracks were observed on the supporting blocks of the centerings when the various arches were concreted.

The blocks were reinforced longitudinally by means of rods 25 mm. (1 inch) in diameter. One hoop was placed inside the longitudinal reinforcement and another outside them.

These hoops were made of steel 32 mm. (1 1/4 inch) in diameter. Pins, likewise 32 mm. in diameter formed the transversal reinforcements and anchored the block to the pier.

Figure 22 (view of the interior of a pier before concreting) shows the reinforcements of the supporting blocks for the centerings as well as those for the supports of the hinge bearings of the concrete arches. The sketch shown in figure 23 gives the details of a block.

These blocks were demolished after completion of the arches.

c) Crown hinge.

This simple and economical hinge at the foot of the centerings did away with the possibility of installing at this place means for removing the centering, such as sand boxes or hydraulic jacks.

All that remained was to instal them at the keystone and to design them so that they formed a hinge at the same time.

In this case, it became a difficult matter to place hydraulic jacks at the heads of the centerings. To ensure proper working of the jack, the play between the piston and the cylinder must be as small as possible and hence a hinge effect is impossible. The slightest movement of the centering, involving a rotation at the head, however small, entailed the risk of jeopardising the working of the jacks.

Resort was had, therefore, to the sand box, arranged horizontally between the heads of the centerings.

The pressure of 500 t. (492 Engl. tons) which these boxes had to transmit necessitated a careful study of their design.

It was no longer possible to rely upon the usual pressures exerted on the sand in these appliances (about 60 kgr./cm² [853 lb. per sq. inch.]), for the boxes would then have had to have an internal diameter of

$$\sqrt{\frac{500\,000 \times 4}{60 \times 3.1416}} = 1.03 \text{ m. } (3 \text{ ft } 4\tfrac{5}{32} \text{ in.})$$

which was practically impossible to allow.

It was necessary, therefore, to put the sand under a greater pressure. What, then, were the permissible limits, and how would the sand behave, especially at the high pressures, from the point of view of its discharge from the outlets when the centering was removed?

In order to ascertain these unknown

(1) This curved surface also allowed the base of the centering to roll on its support while being lifted.

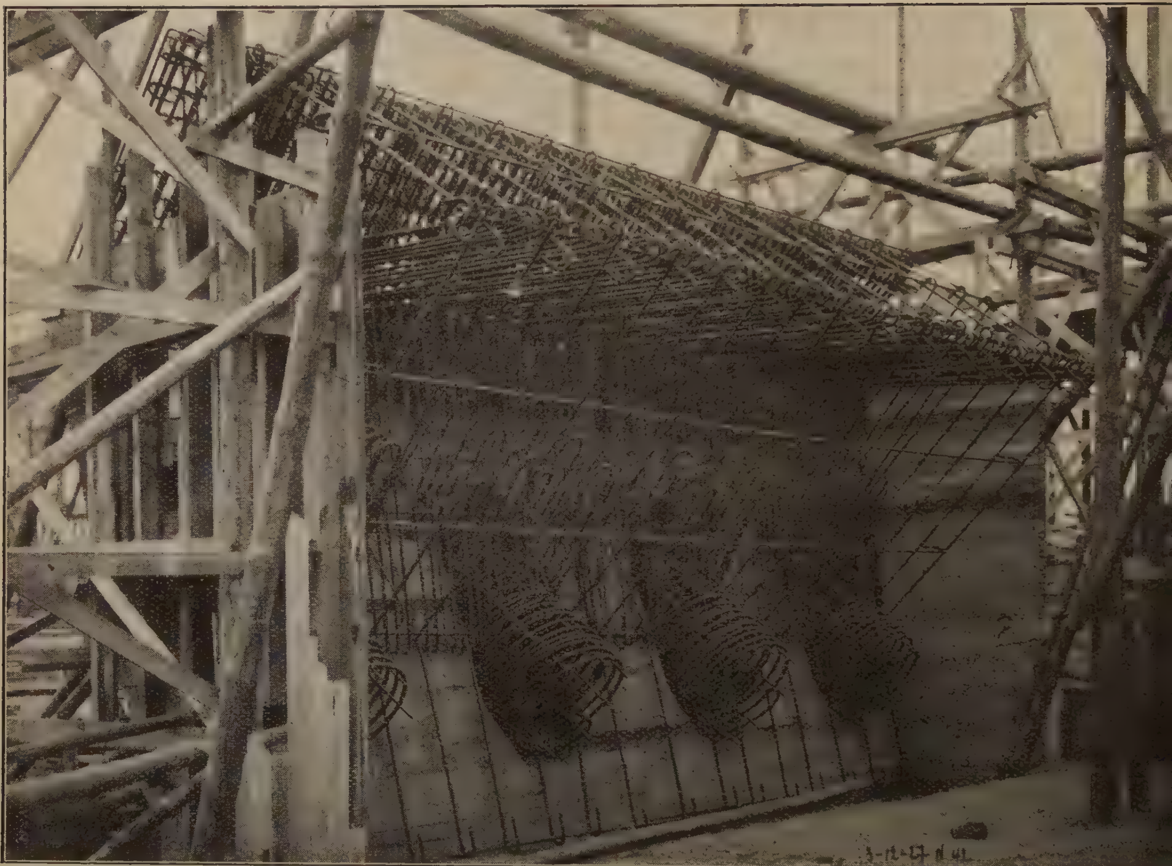


Fig. 22.

factors, tests were carried out by Mr. Baes at the request of the contractors, in the laboratories of the University of Brussels, on a sand box of reduced dimensions, formed of a strong steel cylinder, 133.3 mm. (5 15/64 inches) internal diameter, corresponding to a cross-section of about 140 cm² (21.7 sq. inches).

A solid steel piston 131.8 mm. (5 3/16 inches) in diameter was adapted to slide in this cylinder, thus leaving a play of about 1.5 mm. (0.059 inch).

The head of the piston, in contact with the sand, was provided with a thick hydraulic leather forming a joint with the cylinder. This leather was fixed to the piston by a threaded copper ring.

To avoid the jamming which might have been produced if, despite the precautions taken, any sand found its way past the joint, the piston had a diameter of 131.8 mm. (5 3/16 inches) for a length of 20 mm. (25/32 inch) only, and immediately after, the diameter was smaller,

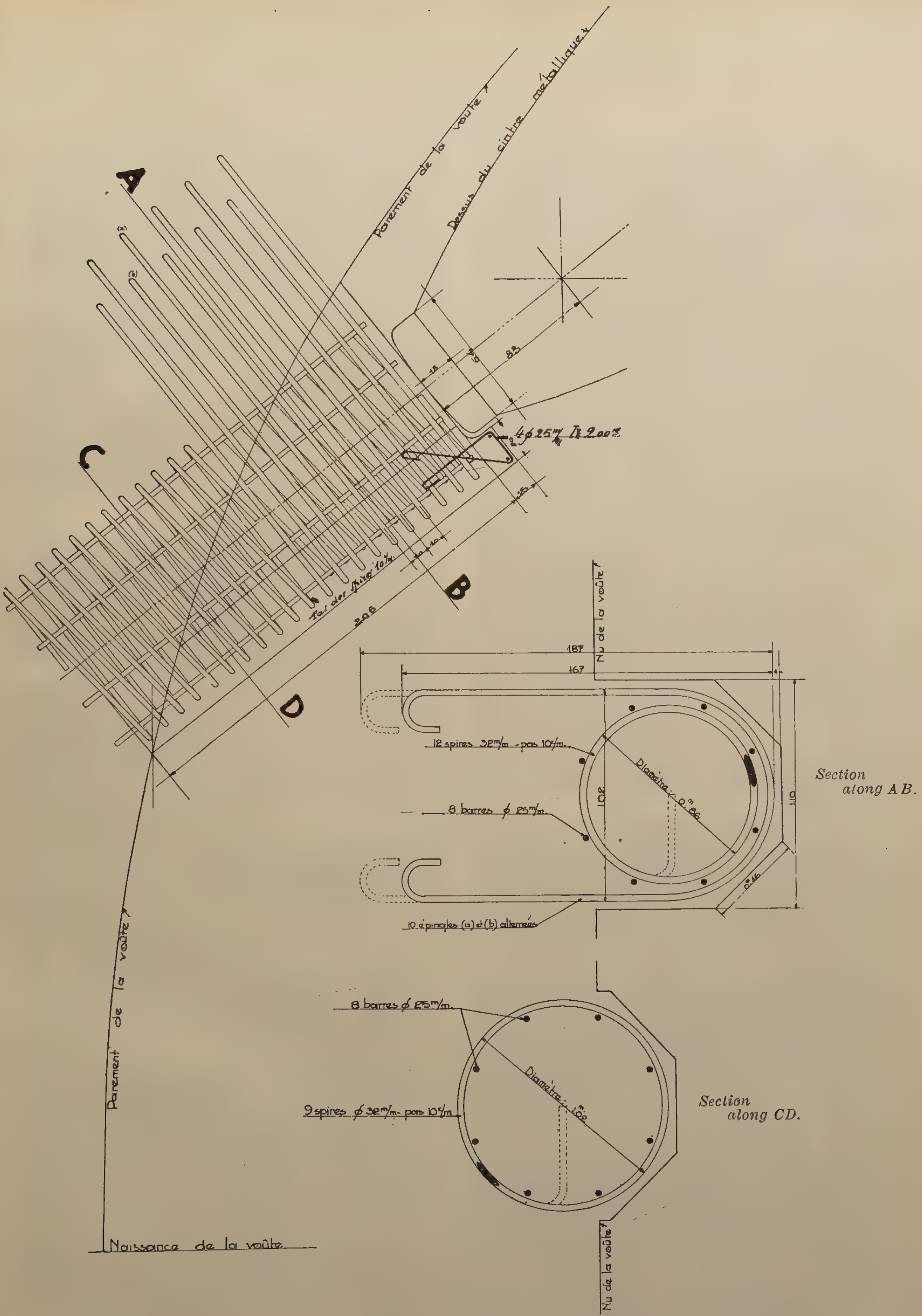


Fig. 23. — Renory viaduct. Constructional details of the supports for the centerings.

Explanation of French terms: Dessus du cintre métallique = Top of steel centering. — Epingle = Pin. — Naissance de la voûte = Springing of arch. — Nu de la voûte = Exposed part of arch. — Parement de la voûte = Face of the arch. — Pas des spires = Pitch of coils.

thus leaving a free space in which any sand could eventually lodge without causing serious disturbance.

So that the piston would be well guided, it was turned in a second place to its maximum diameter of 131.8 mm.

The cylinder was provided in its lower portion with two horizontal openings for the discharge of sand.

The box was filled with Moll sand, dried and sieved, to a depth of 120 mm. (4 23/32 inches), the piston placed in position, and the whole appliance was placed between the plates of an Amsler vertical machine, capable of furnishing a compression of 100 t. (98.4 Engl. tons).

The load was gradually brought to 33 t. (246 kgr. per cm^2) (32.5 Engl. tons [3 500 lb. per sq. inch]). The settling of the sand was considerable (on filling the cylinder, the sand had only been rammed by hand), attaining 5.8 mm. (0.23 inch).

The load of 33 t. was maintained for seven and a half minutes, the settling of the sand increased by another 5 mm. (0.196 inch).

The discharge orifices were then opened. In each of them the sand assumed its natural slope without any being projected outside. The pressure was maintained, the orifices remaining open.

The sand, which had to be removed by means of a small scraper, had not changed in appearance. The orifices were easily closed again under pressure, the sand offering no resistance, and the thickness of the wall being sufficient to allow the natural slope (angle of repose) to be established.

The load was again applied, being raised to 66 t. (468 kgr. per cm^2) (65 Engl. tons [6 656 lb. per sq. inch]). This load was maintained for five and a half minutes.

The stoppers were removed, and again it was necessary to scrape the sand in order to cause it to come out. The sand still ran easily, but its appearance was altered. The grains, when examined under the microscope, were seen to have been crushed, and when held in the hand, the sand left a fine white dust adhering to it, which was not the case for the same sand before the test. When allowed to fall from a low height, it produced small white clouds.

The test was carried to 98.2 t. (700 kgr. per cm^2) (96.7 Engl. tons [9 956 lb. per sq. inch]); the sand was more broken up, but its discharge was still as easy although never spontaneous.

The piston was easily withdrawn, no sand having got past the leather fitting.

The tests were repeated, giving similar results (1).

These results were conclusive, and from them may be deduced the following :

1. Whatever the pressure, the sand does not run spontaneously, but assumes its natural slope in the discharge orifices. The load is supported with the orifices open.

2. Starting from a pressure above 246 kgr. per cm^2 (3 500 lb. per sq. inch) the sand alters in texture.

3. The appliance functions easily, despite a relatively large amount of play between the piston and cylinder.

4. The settling of the sand is slight but not negligible.

The sand box was, therefore, an appliance offering considerable security, working satisfactorily and practicable in cases similar to that in which the load had to be supported for several months. It allowed the piston to be made of such

(1) For further details, the reader is referred to the article which Mr. Baes has published on his experiments in the *Revue Universelle des Mines*, 15 April 1929.

a shape that a slight rotation in the cylinder was possible.

The principle was adopted and it was decided to construct large boxes, it being always understood that :

1. A safety factor of one and a half would be adopted as regards the critical point (alteration in the texture of the sand), which was still not clearly defined. The permissible load on the sand was then fixed at

$$\frac{2 \times 246}{3} = 165 \text{ kgr./cm}^2,$$

(2 347 lb. per sq. inch).

2. The boxes finally selected should be tested in the hydraulic press to a pressure of 800 t. (787.4 Engl. tons).

As regards the settling of the sand, it was decided to provide the box with four strong ties which would be tightened while under the press so that the sand would be unable to become decompressed before the box was placed in position (see figure 24, giving the details of a sand box).

The boxes intended to support 500 t. (492 Engl. tons) were provided with a piston 625 mm. (2 ft. 19/32 inches) in diameter,

$$\frac{165 \times \pi \times \overline{62.5}^2}{4} = 500\ 000 \text{ kgr.}$$

The stroke of this piston was fixed at 500 mm. (1 ft. 7 11/16 inches), this stroke being necessary because the sand had to be removed in order to adjust the centerings, and it was necessary that there should still be sufficient travel, after adjustment, to enable the centerings to be removed after concreting.

The end plates, the bottom of the cylinder and the piston were provided with a cast on disc, projecting 2 cm. (25/32 inch) and intended to ensure the box being correctly centred. This disc engaged in a corresponding opening left in the heads of the centerings.

For the sake of economy, the piston was hollow, with ribs of cast steel. It was ultimately filled, once and for all, with rich concrete.

The thickness of the cylinder was determined by the Geest formula, similar to that given by Lamé, for determining the maximum elastic stress in a thick-walled press cylinder or vessel. It is known that Lamé's formula was deduced for cast iron, while Geest's formula applies to cast steel.

This formula is written :

$$\frac{e}{r} = \sqrt{\frac{1}{1 - \frac{2p}{R}}} - 1$$

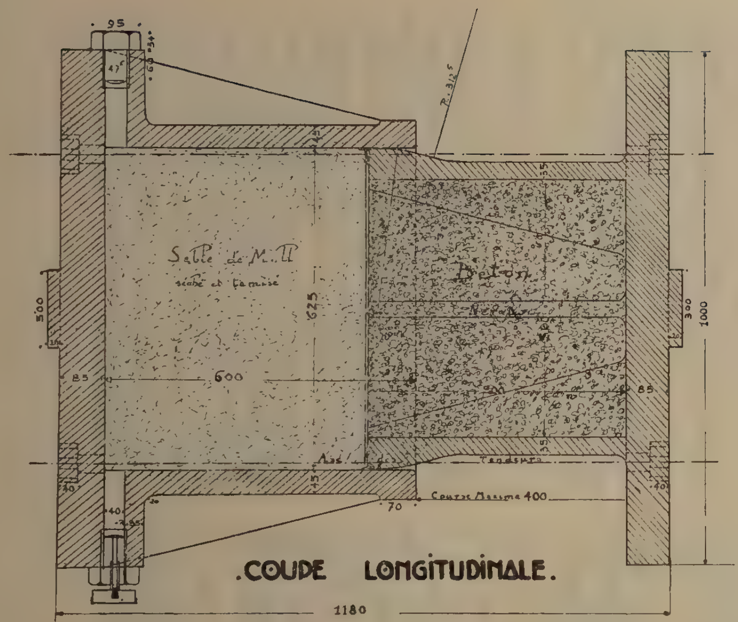
where e = the thickness of the cylinder,
r = the internal radius of the cylinder,
p = the internal pressure (normal to the walls),
R = the admissible tensile stress.

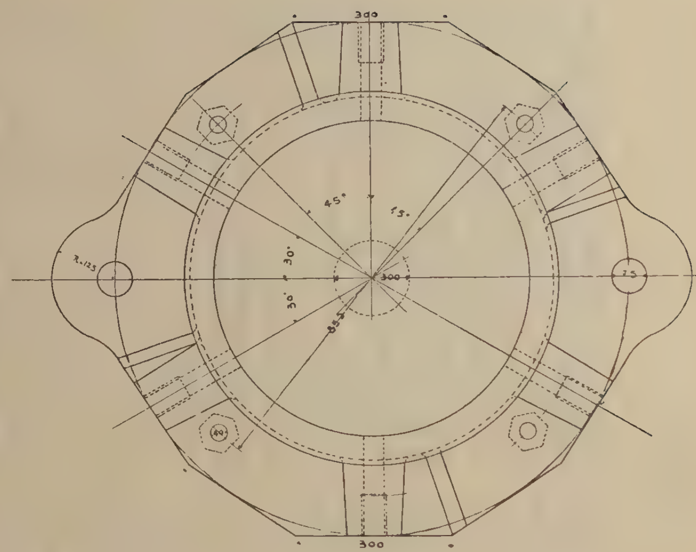
It was now necessary to determine the value to be given to p.

It was assumed that $p = \frac{1}{4}$ of the axial pressure. In fact, it may be shown in the following manner that the radial pressure, in the case under consideration, is less than, or at least equal to, one quarter the axial pressure.

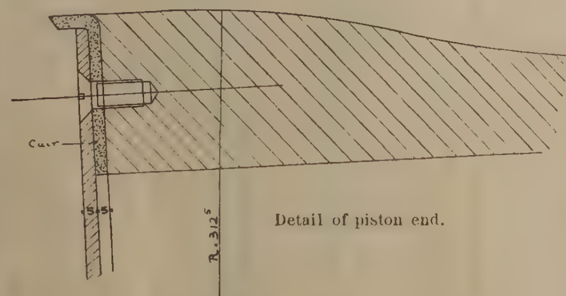
Experiment shows that a mass of materials in powder form is unable to retain any particular shape or resist external forces unless it develops a system of elastic pressures, such that all the principal forces are compressions.

The ratio of the extreme principal compressions in a given point should be





Plan of cylinder.



Detail of piston end.

Fig. 24. — 500-t. (492- Englishton) sand box.

Explanation of French terms: Course maxima = Maximum stroke. — Cuir = Leather. — Sable de Moll etc. = Moll sand, dried and sieved.

less than a characteristic coefficient of friction of the material. In fact, for these materials, equilibrium is only possible if the angle made by the elastic force with the normal to the element of surface is less than the angle of friction of the grains one upon the other.

The result of this is that the circle of Mohr for the elastic forces is at every point less than the cone of friction as shown in the diagram in figure 25.

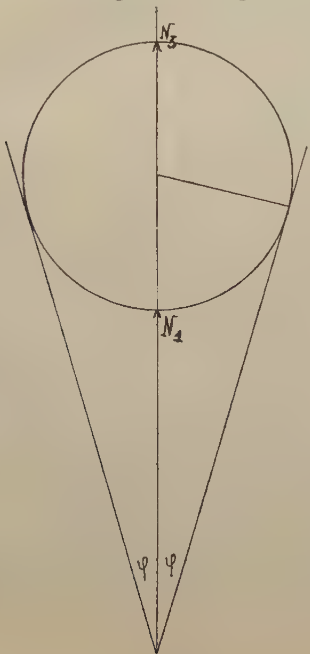


Fig. 25.

N_1 and N_3 being the extreme principal forces, $\dfrac{N_1 + N_3}{2}$ is the ordinate of the centre of the circle and $\dfrac{N_3 - N_1}{2}$ is the radius of the circle, whence

$$\frac{N_3 - N_1}{N_1 + N_3} < \sin \varphi$$

$$\frac{N_1}{N_3}\,\frac{1 - \sin \varphi}{1 + \sin \varphi} = \tan^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right) \times \frac{N_1}{N_3}$$

In the case under consideration of a piston sliding in a cylindrical body, the materials in powder form move to give a decrease in the generatrix and an increase in the sectional area.

The direction of these movements necessarily involves a compression $N_3 > N_1$ on the right sections and a compression $N_1 < N_3$ in the radial direction.

When the load carried by the piston is gradually increased, the compression N_1, starting from zero, gradually increases and attains the value

$$N_1 = N_3 \frac{1 - \sin \varphi}{1 + \sin \varphi}$$

Until N_1 reaches this value, there is no equilibrium, but as soon as this value is attained equilibrium is stable and consequently N_1 will no longer tend to increase further and the value adopted for N_1 will be therefore

$$N_1 = N_3 \frac{1 - \sin \varphi}{1 + \sin \varphi} = N_3 \tan^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right).$$

For sand and for pressures varying from 0 to 200 and 300 kgr. per cm² (0 to 2 845 and 4 267 lb. per sq. inch) the angle of friction repose is at least 37°, which gives

$$\tan^2\left(\frac{\pi}{4} - \frac{37}{2}\right) = \tan^2 26^\circ 30' = 0.248.$$

The radial pressure is thus less than a quarter of the axial pressure.

The wall of the box was therefore given a thickness of 45 mm. (1 49/64 inches)

$$\frac{e}{r} = \frac{45}{625} = 0.072$$

$$p = \frac{165}{4} = 41.25$$

$$R = \frac{2p\left(1+\frac{e}{r}\right)^2}{\left(1+\frac{e}{r}\right)^2-1} = \frac{82.5 \times \overline{1.072}^2}{\overline{1.072}^2 - 1} = \frac{82.5 \times 1.149}{0.149} = 636.2 \text{ kgr./cm}^2.$$

$$= (9\,049 \text{ lb. per sq. inch}).$$

Bach gives as admissible load 900 to 1 500 kgr. per cm² (12 800 to 21 330 lb. per sq. inch).

We were working therefore with complete safety, as was shown by experience. It was indispensable to adopt a considerable safety factor, because the failure of the sand boxes would have involved at least a considerable delay and a large expenditure, and might have caused a serious accident.

B. — *Erecting the centerings.*

The centerings were constructed in riveted sections, and for the purposes of erection, these sections were assembled by means of bolts.

When it was possible completely to assemble the centerings on the ground itself, the following procedure was adopted :

In order to set up the centerings, four timber trestles of 7×15 (2 3/4×6-inch) joists were constructed between them. The timber trestles were assembled by means of bolts and clamps, two being 21 m. (68 ft. 10 in.) high and two 14 m. (45 ft. 11 in.) high.

These trestles were stable in themselves, and did not therefore require stays. They thus gave every safety, which would not have been the case had erecting derricks been used as is the usual practice.

The sand box was fixed at the head of a half centering. Each half centering was moored in two points, one near the head and the other near the foot. The cables thus fixed passed through a tackle, suspended at the head of the trestles and were wound on the drums of electric winches. There were thus four winches for placing each centering in position, two for each half-centering.

This procedure was very rapid, seeing that a 60-t. (59 Engl. tons) centering was thus lifted and placed in position, and the sand box centered, in 48 minutes.

Figure 26 shows a centering in the course of erection. On the truck in the foreground will be noticed a sand box ready for use.

In other places, it was not possible to assemble the centerings on the ground. It was necessary to construct considerable scaffoldings to protect the streets, and to assemble the centerings on these scaffolds piece by piece. One of these instances is shown in figure 27. A kind of overhead crane was erected, the runway of which was, as customary in the works, constructed of joists assembled by means of bolts and clamps. The travelling crane although primitive (a winch fixed on girders placed on truck bogies) had electrically driven lift and travelling gear.

Above the tracks of the Nord Belge Railway Company, at Sclessin, there was not even sufficient place between the loading gauge and the underneath portion of the centerings to set up erecting scaffolds.

It was therefore necessary to launch the centerings over the tracks, just as a bridge is launched.

For this purpose, the construction of pier No. 2 was stopped at the desired

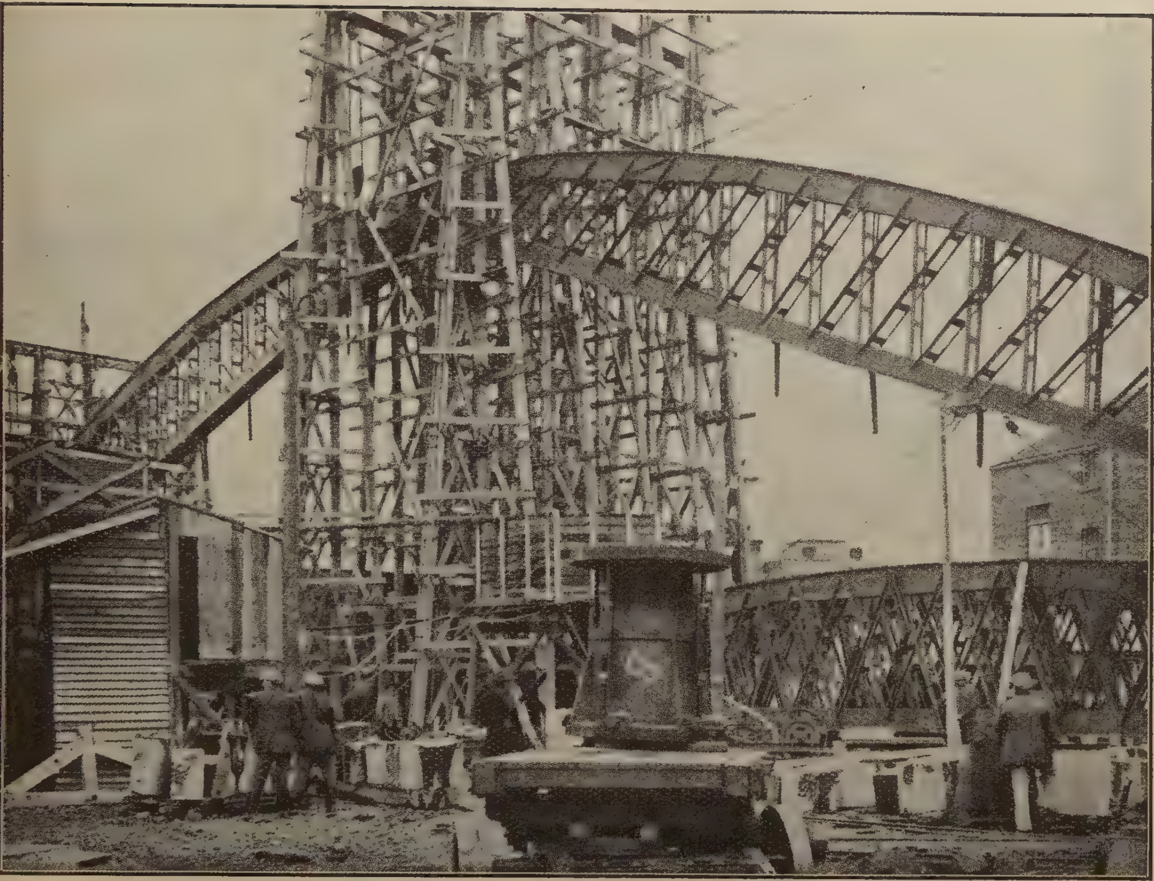


Fig. 26.

level, the somewhat primitive devices for throwing the centerings (truck bogies turned upside down and coupled together) were placed on the concrete (fig. 28) and the centerings, assembled on scaffolds behind the pier, were gradually advanced.

For the three arches spanning the Meuse, it was the first intention to assemble the centerings by means of scaffolds erected on boats moored to the banks, the boats being afterwards towed to the desired spot.

This plan had to be abandoned, because it was only applicable for the central arch, which alone was wholly in the river. For the two adjacent arches, which were situated almost half over the water, and half over the bank, it was inadmissible, and its use for one arch alone became prohibitive.

Piles were therefore driven in the river

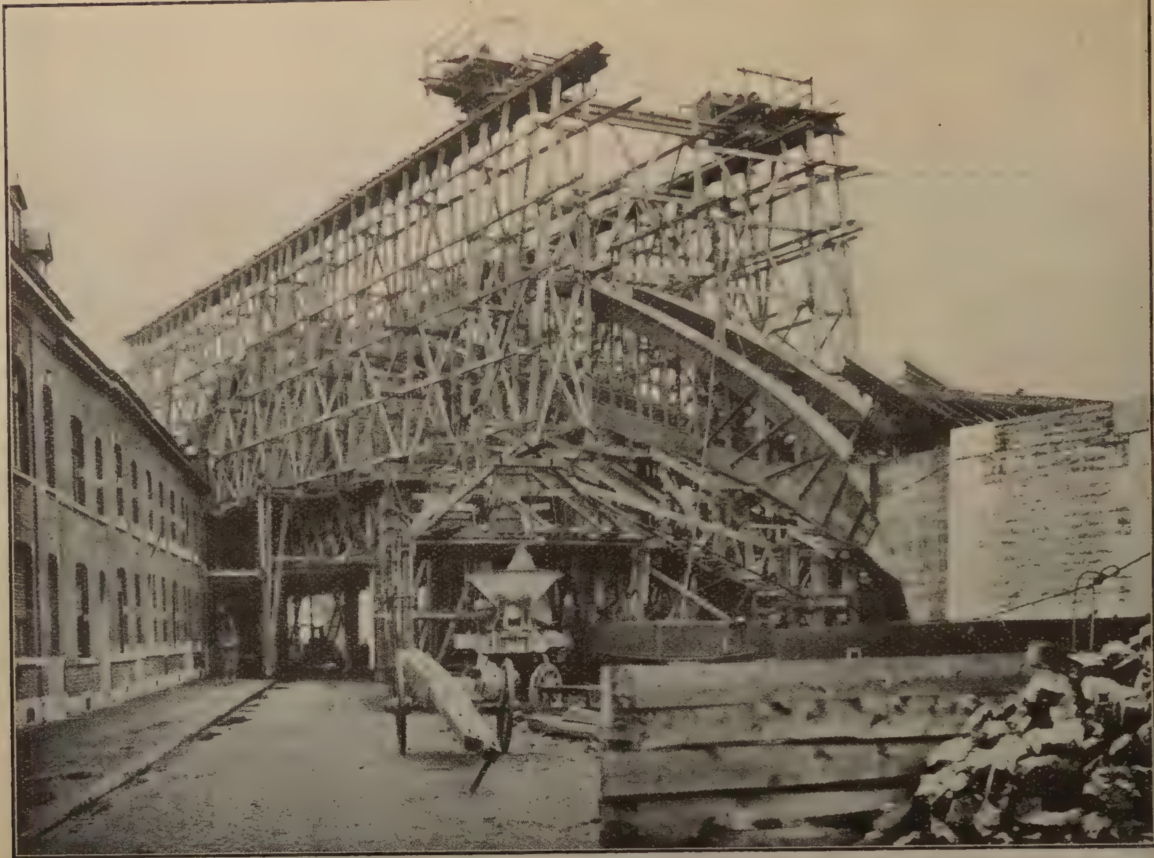


Fig. 27.

Fig. 28.

bed. Steel girders from an old bridge that was being dismantled at Liége were fixed on these piles, leaving in each arch a navigable passage 20 m. (65 ft. 7 in.) wide.

A floor was set up on these girders, and the erection of the centerings in the Meuse was then proceeded with as on solid ground, the centerings being first of all assembled and then lifted in one piece. Figure 29 will enable some idea to be gathered of the procedure for one arch. On the neighbouring arch will be seen, suspended from the centerings which have been placed in position, the steel girders which were used to erect them, and ready to be lowered into boats (the piles which supported the girders have already been removed).

C. — *Adjustment of the centerings.*

The four centerings being erected and stayed, and the lagging being ready, two voussoirs, extending across the key, were concreted on the arch so as to load the centerings, and at the same time the sand boxes were allowed to discharge until the centerings had been lowered to the required level.

As a precautionary measure, the centerings were kept one or two centimetres above this level, the sand box being an irreversible mechanism.

It was essential to load the centerings before proceeding to adjust them, their dead weight being insufficient to overcome the frictional resistances within the sand boxes. If any other procedure had been adopted, there would have been the risk of producing a cavity in the sand boxes, which, the moment the load reached a sufficient value, would have resulted in a sudden drop, with shock, of the centerings, detrimental to the concreting.

D. — *Centering for the arch of 34.00-m. (111 ft. 6 in.) span.*

For this single arch, the erection of steel centerings would have entailed too great an expense.

The Railway Administration allowed the steel to be replaced by timber for centerings designed according to the fan type (figure 30).

The fans were formed of round timbers about 20 cm. (7 7/8 inches) in diameter, and the curve for the arch intrados was made of four 7 × 15-cm. (2 3/4 × 6-inch) joists nailed flat to the ends of the round timbers.

Five identical roof timbers supported the planking on which concreting was done.

The centerings were supported on rows of piles driven completely home and suitably stayed in both directions, like the centerings themselves, in order to avoid any deformation or bulging. The method of removing the centerings which was adopted was that using wedges.

E. — *Removing the centerings from the 61.40-m. (201 ft.-6 in.) arches.*

As in placing the centerings in position, their removal was effected in two different ways, according as to whether the centerings could be lowered in one piece or had to be removed in sections.

In the first case, openings 0.60 m × 0.60 m. (1 ft. 11 5/8 in.×1 ft. 11 5/8 in.) (2 for each half centering) were left in the arch, enabling the centerings to be moored and to allow the tackle to pass through during the work. The electric winches were those which had been used for erecting the centerings. They were installed on the arches (figure 31 shows this method of removing the centerings very clearly).

Fig. 29.

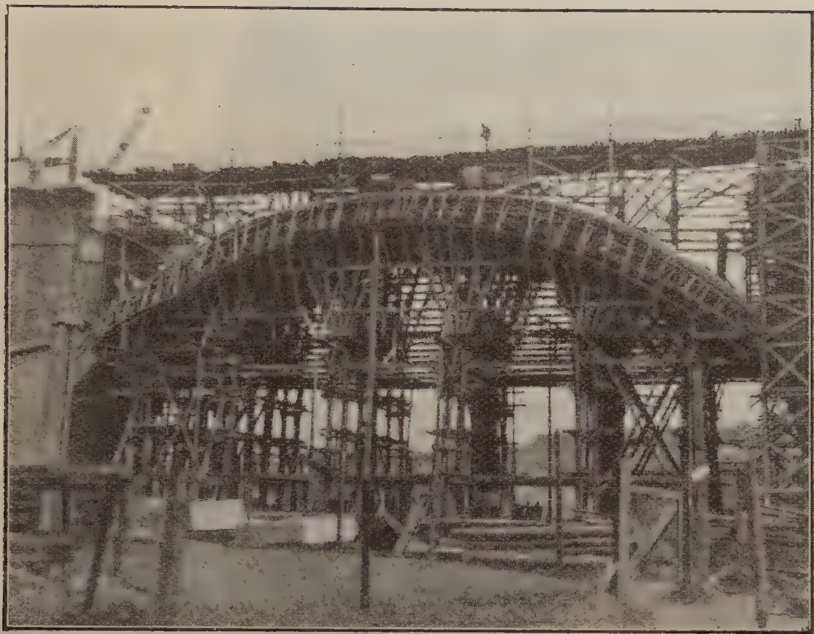


Fig. 30.

In the second case, small and more numerous openings were left in the arch, allowing the centerings to be tied up in order to lower them piece by piece.

These openings were filled with concrete after removal of the centerings. Reinforcing rods, bent temporarily against the walls, were placed beforehand in the 0.60 × 0.60-m. openings, and were knocked down at the moment of concreting.

F. — *Shuttering and concreting.*

The shuttering did not offer anything very particular.

The laggings for the large arches were made of 7×15-cm. (2 3/4-inch×6-inch) planks placed on edge one against the other. Those of the small arch were made of the same planks placed on the flat (the distances were shorter — five centerings instead of four and the loads due to the concrete were much less).

The lateral walls of the arches were made of detachable panels, easy to erect, take down and transport.

Once the shutterings were in position (intrados and the head wall of the arches) each half arch was divided into twelve voussoirs, separated by intervals or joints only 6 cm. (2 3/8 inches) thick.

For this purpose, every other voussoir was lagged in the ordinary manner. After concreting the voussoir, the shuttering was removed, and in order to shutter the intermediate voussoir, a series of groups of three flat iron bars were aligned against the concrete of the fi-

Fig. 31.

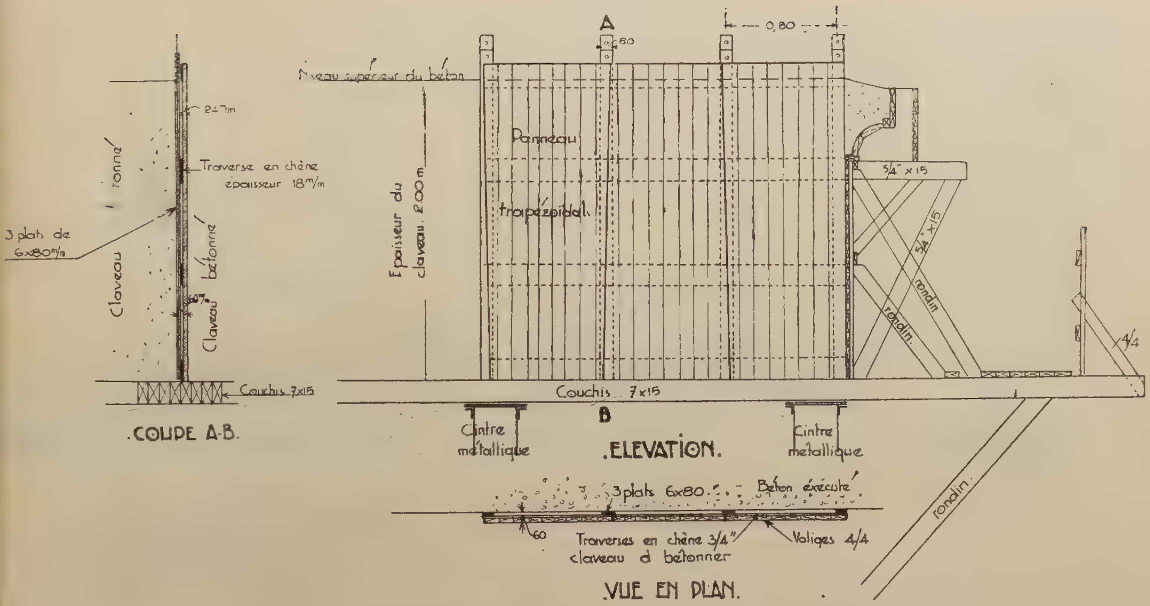


Fig. 32. — Lagging device for the voussoirs, with 60-mm. (2 3/8-inch) joints.

Explanation of French terms:

Béton exécuté = Constructed concrete. — Cintre métallique = Steel centering. — Claveau à bétonner = Voussoir to be concreted. — Claveau bétonné = Concreted voussoir. — Couchis = Bed. — Coupe A-B = Section along A-B. — Epaisseur du claveau = Thickness of voussoir. — Niveau supérieur, etc. = Upper level of concrete. — Panneau trapézoïdal = Trapezoïdal panel. — Plat = Flat bar. — Rondins = Round timbers. — Traverses en chêne = Oak cross pieces. — Voliges = Planks. — Vue en plan = Plan.

nished voussoirs. These bars were greased beforehand and their height exceeded that of the voussoirs, the middle flat bar being the longest. The panels of board, of trapezoidal shape to facilitate removal of the shuttering, rested against these bars (fig. 32). In order to remove the shuttering the middle bar was first withdrawn, sliding fairly readily between the two adjacent bars, which were then withdrawn. In this way, behind the panels of boarding, the freedom, indispensable for unwedging and removing them, was obtained.

The shuttering of the tympans, cornices, corbels and corbelled footways was likewise made of detachable panels, the chief difficulty being to maintain them in position at a height of about 18 m. (59 feet). This was accomplished either by means of light scaffolds rising from the ground, or by means of a kind of timber portals supported on the extrados of the arches and arcades. The shutterings properly speaking where then suspended.

These shutterings had been carefully designed, they were easy to place in position and remove, being assembled merely by means of a few bolts.

For the concreting a foot bridge was erected as the work advanced at a level higher than the arcade pavements and extending over the entire length of the work. The concrete was hoisted in skips by means of a powerful derrick (90 H.P.)

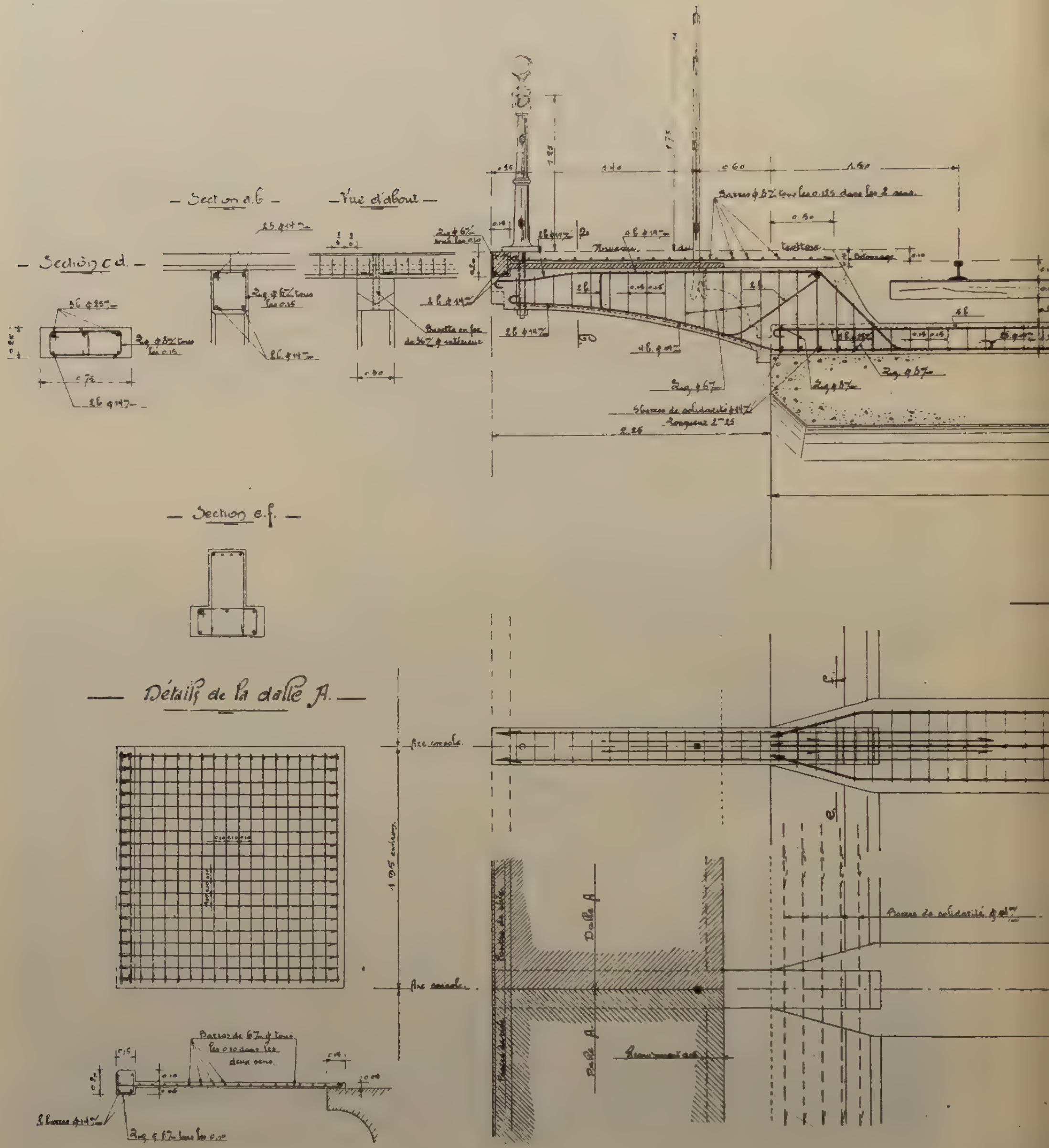
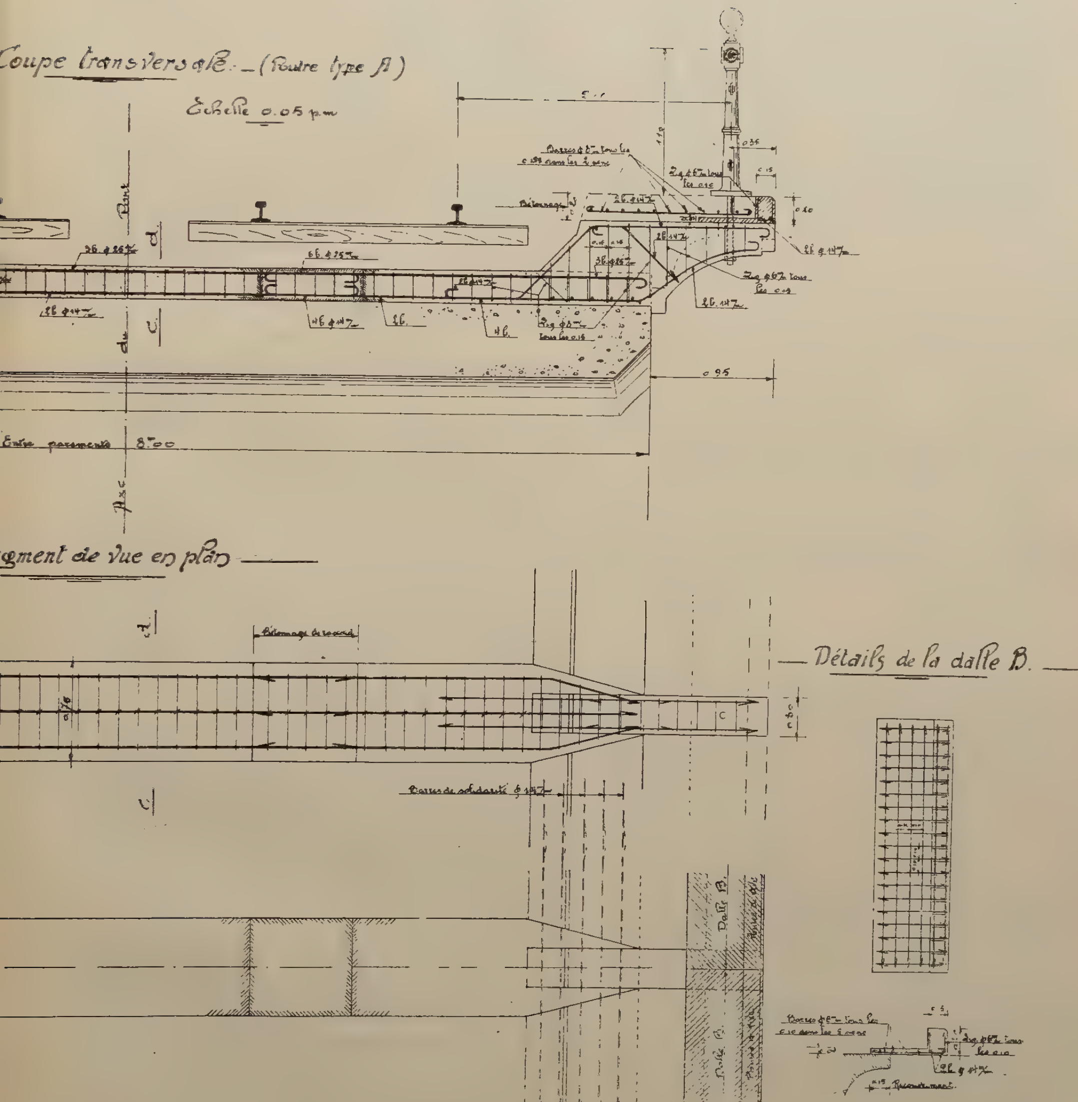


Fig. 33. — Renory viaduct. M

Explanatio

Axe console = Axis of bracket. — Barres de solidarité... longueur... = Binding bars... length... — Barres de... tous les... etc. = Cross section (« A » type girder). — Détails de la dalle = Details of the slab. — Entre parements = Distance betwe d'about = End view.



. Footbridge for pedestrians.

terms:

ens = Bars... in diameter placed every... inches in both directions. — Busette en fer = Steel pipe. — Coupe transversale, Fragment de vue en plan = Part plan. — Niveau du trottoir = Level of pavement. — Recouvrement = Lap. — Vue

installed on one pier. The trucks were wheeled to the place of use, where the concrete was lowered by means of channels to be used for concreting the arches, covering pavements of the arcades, piers or footways.

We shall return for a moment to the composition of the concrete, which has already been discussed in the first part of this article.

This concrete was of a slightly moist consistency for the arches (without reinforcement) where it was rammed by means of compressed air. It was more fluid for hand ramming between the reinforcements of the arcades and in the small parts of the cornices.

The fluidity of the concrete was tested from time to time by the classical method of the Abrams cone. The amount of settling had to be between 10 and 15 mm. (3/8 and 5/8 inch) only for the concrete intended for the arches, and in the neighbourhood of 30 mm. (1 1/4 inches) for the concrete to be placed between the reinforcements.

As regards the composition of the mixture from the point of view of the inert material, it was determined from time to time by a fineness test. It was in this way, moreover, that the previously mentioned composition of 1 000 l. (35.2 cubic feet) of 0/60 (2 3/8-inch) gravel and 125 l. (4.4 cubic feet) of Rhine sand had been fixed. The fineness curve obtained by adding that of the Rhine sand to that of the 0/60 gravel in the proportions indicated approached very closely the ideal curve corresponding for the fluidity in view, with the maximum dimension of the constituent elements (60 mm. = 2 3/8 inches).

On the basis of these tests, the quantity of Rhine sand to be added varied from 100 to 125 l. (3.52 to 4.4 cubic feet) according to the particle size composition of the 0/60 unsorted gravel as revealed by sieving tests.

In the same way, the composition of the 0/30 (1 3/16-inch) mixture was controlled. In this way, it was found that at one time the supplies of 0/30 were containing too much fine material. It was possible to approach the ideal curve by adding a certain proportion of classified 5/20 (3/16 to 13/16-inch) gravel.

Proceeding in this way, a mixture was obtained, the efficiency of which was practically constant. One of the advantages of this constancy was that it was possible to establish almost certainly, without requiring measurements, merely by keeping an account of the mixtures, the cubic contents of the work effected with the view to compiling the intermediate payments.

As regards these questions relating to the efficiency of cement, which are so important to contractors, it has been thought useful to bring to their notice and to that of engineers, the interesting paper which has been published on this subject by Mr. Paul Leclercq, technical inspector of the Belgian National Railway Company, directly attached to the constructional works of the Renory viaduct [1]. Mr. Leclercq has recorded in his paper a large number of observations and experiments carefully made over a period of many years on many large works, and has indicated the practical conclusions to be deduced therefrom.

In order to follow the movement of the steel centerings during concreting, rigid, indeformable rods had been suspended from the centerings at various places (three for each half centering). These

(1) *Bulletin technique de l'Union professionnelle des inspcteurs techniques et des chefs de section des Chemins de fer belges*, number for the 15 December 1929.

rods moved in front of a graduated scale fixed in a concrete block on the ground.

The order in which the voussoirs were concreted was left open to modification in case any abnormal deformation was revealed.

This method enabled the sinking of the centerings at the key to be checked. In all cases, it was found to be in the neighbourhood of 50 mm. (1 31/32 inches), the calculated deflection.

As soon as the voussoirs were concreted, a start was made with the concreting of the joints. When this was finished, and after allowing the joints to set for 15 days, the centerings were removed, that is to say, three or four weeks after the last voussoir had been concreted.

By proceeding in this way, the voussoirs had undergone a large part of their contraction, and the filling of the joints to refusal caused a sort of automatic release of the centerings. The drop of the concrete arches, after the centerings had been properly removed was always very slight [from 0 to 10 mm. (25/64 inch)].

There is yet another detail concerning the concreting which, we believe, deserves mention, and that is the device adopted to remove the traces of the joints due to intervals in the working, and which appeared on the facing.

We have said that the visible facings were done in fine concrete (gravel 0/5 [3/16 inch] and Rhine sand). Whatever care was taken with the concreting and despite the fineness of the constituent elements the joints due to intervals in the concreting appeared when the shuttering was removed.

In order to remedy this imperfection in the work, only strictly horizontal joints were allowed in concreting the facings, and it was decided to proceed in the following manner : Before concreting was recommenced, a layer of mortar of ordinary fluidity, composed of Rhine sand and Portland sand was spread on the concrete previously put down, in contact with the lagging. Concreting was immediately recommended on this layer of mortar and the concrete was thoroughly rammed. In this way, interpenetration of the concrete and mortar was obtained, with almost complete absence of thin zones revealing the place where work had been resumed.

In brief, well mixed mortar feeds the joint, while cement grout although ensuring within the mass a union which is sufficient in practice, runs away at the facing, leaving the lips of the joint visible.

In the case where minute cavities or cells may still have remained, the joint due to resumption of work coincided, owing to its horizontal position, with the unavoidable projections due to the lagging, the boards being likewise arranged horizontally.

The result was excellent, and the joints may be said to have been imperceptible. The Belgian National Railway Company were thus able to do without the granulation originally intended and on that account to effect a considerable saving.

3. *Footbridge for pedestrians.*

The construction of the viaduct was already considerably advanced when, at the pressing request of the neighbouring works and the local authorities, it was decided to add a footbridge for pedestrians along the extent of the arches in the Meuse and of that crossing the roads of the port of Renory.

The difficulty lay in the considerable increase in the overhang of the brackets caused by the erection of this bridge. In

fact, the original plan comprised a projecting service footbridge, to extend from end to end of the viaduct and to project 0.85 m. (2 ft. 9 1/2 in.).

Consequently, the addition of a 1.40 m. (4 ft. 7 1/8 in.) bridge for pedestrians brought this overhang to 2.25 m. (7 ft. 4 5/8 in.).

It has been mentioned previously that this footbridge extended over the Meuse and the railway lines, that is to say, that it was not possible, except at considerable expense, to support the laggings at a height of about 16 m. (52 ft. 6 in.) by means of scaffolding placed on the ground.

In these circumstances, the contractors proposed to the Belgian National Railway Company to precast the brackets on the ground and then to hoist them up into position.

The brackets were provided with a concrete counter-weight adapted to ensure stability of the whole (fig. 33) until the pavement had been laid and concreted.

The power of the works' cranes was sufficient to allow this operation to be successfully accomplished.

In this way, support became unnecessary, an advantageous result from the point of view of the cost.

This reduction in cost was also accom-

panied by the appreciable saving resulting from manufacturing on the ground.

After erection, the brackets for the footbridge for pedestrians (downstream side) were connected to the ordinary brackets of the service footbridge situated on the upstream side of the work, by means of connecting girders.

This at once suggested that the ordinary brackets should be made in the same way (cast pieces).

In brief, the standard arrangement consisted of two brackets connected by a transverse girder, resting either on the main arch directly or through the medium of small walls, well stayed together, or on the load-distributing arcades. The whole arrangement was anchored rigidly to the tympans, which in their turn were solid with the arch.

There still remained the walling to be constructed. To make this easier and more economical, walled paving slabs 4 cm. (1 9/16 inches) thick were utilised, the thickness not affecting the strength of the walling.

These paving slabs, stiffened by the edge wall, were likewise made by mass production, and placed in position by means of cranes.

The advantage of the procedure was to entirely do away with placing shuttering, both for the brackets and for the walling. It would have been very difficult to remove the shuttering from the walling without resorting to expensive scaffolding.

An excellent result was obtained by this method. The visible portions, formed by the brackets and concrete paving, having been made on the ground, it has been possible to take particular care with them, a fortunate element as regards their appearance.

Although there are undoubtedly many more constructional methods to be described, which, however, we are afraid would go too far beyond the scope of this survey, we shall close by inviting the reader to examine figures 34 and 35. They enable some idea to be gathered of, in one case, the extent of the works, and in the other the appearance of a portion of the viaduct in the course of completion, and are a credit to Messrs. L. Pêche and A. Ronsse, the Directors of the Special Construction Department of the Belgian National Railway Company, who presided over the destiny of the viaduct as well as to the constructors : Messrs. the Société d'Entreprise Générale de travaux « Engetra » and Messrs. Léon Monnoyer et Fils.

[385 .524 (.44) & 656 .212.9 (.44)]

Note on the application of premiums for improved output in the marshalling yards of the French Est Railway.

FOREWORD.

The actual output of work in yards where trains are formed and where wagons are shunted to make up these trains, known as marshalling yards, depends upon several factors.

The different phases of the work to be done are carried out in turn in different parts of these yards, known as sections.

In each section the work is done by means of shunting engines, the number of which moreover varies by using in turn the successive grids of marshalling sidings laid on ground with different inclinations, according to the nature of the period of the complete cycle that takes place therein.

The number of the engines in each section varies : it may be nil at certain times but for a given section built in a given manner it is not possible to exceed a certain figure, a function of the material equipment of this section : above this figure the total work done by the engines does not increase any further, the hindrance to the output of each engine by the presence of the others counterbalancing the improvement which should result from this additional power.

In order to increase the work done in a section, or to raise the level of its possibilities it is therefore necessary after a certain moment not to count any more upon increasing the number of the shunting engines in it, but on the increase in the output of each of these engines.

1. For that it is possible to re-arrange the shapes of the grids : their more or less harmonious layout makes it possible to use them more or less profitably; it is the constant preoccupation of the Railway Companies to introduce, when getting out any new marshalling yards, the improvements that previous experience has suggested, and it can be said that an ideal type plan has been arrived at already, to which it is no longer necessary in each case to do more than introduce the modifications needed by local contingencies or improvements in detail which should make it possible in each kind of yard to shunt with ease and with the maximum movements at the same time.

The rapidity and certainty with which these means can be used now play a prime role, and the design of the boxes required to work them has brought out particularly successful solutions of this delicate problem.

2. Already the Companies also are considering a systematic investigation into the down gradients to be given to the different planes in the marshalling yards, in order to get from gravity the maximum assistance to the work of the en-

gines : there is in this direction work which will take a long time to complete, and which cannot have anything but good results, the first of which have already made themselves felt.

The question is moreover complicated, as it involves the investigation into the apparatus required to counterbalance the effect of the down gradients when it becomes momentarily excessive : as the development of the circulation of trains on the great arteries of traffic currents has brought out various systems of spacing the trains which are used everywhere today, the development of the output of the marshalling yards has brought out the need for spacing the wagons when passing through the important points in the yards. But the means employed so for to separate the trains (with rare exceptions) were taken by the drivers of these trains and were purely moral. Those which had to be considered when separating wagons, although they are not coupled to any machine and move each one through the impulsion given it previously, had to be entirely mechanical. It is therefore a problem entirely different from the preceding one but which at the present time is already nearing solution.

3. The need for spacing the wagons involves the need for inter-communications between the different boxes by which the vehicles are separated out : a complex question to which the telephone only provides a partial solution. The engineers in dealing with such questions have built extremely varied types of apparatus, but each answering to a certain well determined end and solving the problem for a particular point of the movement of the wagons inside the marshalling yards.

4. From what has been said at the beginning of this note there is the greatest interest in limiting the use of shunting engines to the work for which alone they are indispensable : there should result at each moment an immediate economy in the expenditure resulting from this very costly use of engines, and there should result above all an increase in the level of the possible work the section concerned can do.

The Companies are dealing with this question the more urgently as the time lost by the engines in doing these parasitic operations can be 30 to 50 % of their time in service. This shows the importance of this problem the cost of which, by the putting into service of the solutions to the points dealt with previously, ought to be reduced, and to which the Companies have already brought specific solutions which vary widely from one country to another.

* * *

For some time the French Est Railway has had under consideration the solutions to be taken to solve the different problems we have just mentioned.

The construction of marshalling yards such as those at Lumes and Blainville and the use of electric signal boxes for shunting and forming trains of a special type introduced before the War, meet the requirements dealt with under 1.

The same may be said as regards the schemes for constructing yards now being carried out, and the proposed extension of the use of electric shunting and making up boxes in marshalling yards whether already existing or proposed (Vaires, Conflans, etc.).

The alterations made to the gradient sections of old marshalling yards, the rules having determined the profile of the marshalling yards under construction, have had as object to make the greatest possible use of gravity in the working of the yards.

The installation in various yards of retarders varying according to the position in which they are placed and the use to which they are intended (brake at the top of the hump, brake at the bottom of the hump, and in the zone of the points by slipper and rail brakes) have had as their reason the moderation of this action when it has at any time shown itself too violent.

Intercommunication apparatus between the boxes, daylight shunting signals, revolving day light signals connecting the hump (or the pointsmen) and the brakemen, acoustic signals protecting the crossings, apparatus for distributing messages, indicate by their multiciplicity the degree of interest that the Est Company takes in the question of communications between the different people in the yards.

Finally this Railway in order to reduce the time lost by the shunting locomotives in carrying out unproductive work, has introduced in the Blainville marshalling yard road tractors similar in type to the tractors used on farms or in vineyards.

These tractors have made it possible to increase the work done per engine-hour in the different shunting yards (that in the shunting out yard has been increased by 50 % [1]), and to raise by as much the level of the work the yard is capable of doing. If the first result is appreciable, the second is still greater. The Est Railway in consequence is proposing to extend without delay the use of these tractors in the other marshalling yards, the size of which justifies their employment.

But however excellent the methods used to improve the work done by the locomotives and as a consequence both an improvement in the work done in the different sections of the yards as well as a raising of the possible capacity of these yards, these methods would be without effect if the staff using them did not bring to its work the whole of the diligence and intelligence needed. There is therefore alongside the material factors a moral and psychological factor of undoubted importance, the measure of which will be given later on.

By taking into account this factor the French Est, to the example moreover of other Railways, proposes also to increase the work done in its marshalling yards by instituting for the benefit of the staff working therein, premiums for good output, the present note having as its object the indication of the principles under which these premiums have been established.

Principles.

In order to understand the principles followed when introducing output premiums, the two points previously indicated should first of all be remembered :

1. That the different phases of the work to be done in a marshalling yard are carried out in turn in different parts of each of these yards known as sections: each of these sections without being entirely independent of the others forms however a unit which can be considered as one of the cells of which the marshalling yards are composed.

2. That the number of engines in each section is variable, that it may be nil and that for a given section arranged in a

(1) The savings in shunting engine-hours as a result of this increase in output has been in March 9106, representing a saving of 318 000 fr. Other economies due to this but which it would be difficult to evaluate have been obtained, such as less damage to stock, as well as the shorter time the wagons remain in the marshalling yards.

given manner it cannot exceed a certain figure.

The result of this is that an improvement in the use of the engines brings with it not only an economy in the working of the yard, but in addition raises the level of the possibile work that can be done in this yard or at least in the section interested.

In addition, if the work done by the staff can result in a reduction of costs and raise the amount of work that can be done, it cannot itself develop the traffic through the marshalling yards, this traffic depending above all upon the geographical position of the marshalling yard.

Based upon these three considerations we arrive at the main idea of output per section, and per hour of engine used.

In addition, in each of the sections of a marshalling yard, which as we have previously mentioned acts as a cell, there are found a certain number of men whose work is closely connected and who should work in close collaboration : this is true not only of the men who work at the same time in the section but also of all those who work in it in turn eight hours within one day as a result of the eight-hour day (3 × 8).

Based on this new factor, we arrive at the second main idea that the premium which should recompense an improvement in the output per engine-hour ought to be collective and should be attributed not only to the whole of the men who work together at the same time in this section, but to the whole of the groups which works therein during a complete cycle of 24 hours.

Thus, the average output a section gets from its engines every 24 hours having been determined previously to drawing up the premium scheme, every time that this section during a period of 24 hours has a higher output than the average, its output premium would be granted to the whole of the men having worked in the section during the period considered. This premium naturally would be the greater as the extra work done was more than the average.

Determination of work done.

In order to be able to determine the output per engine, hour used it is essential to know the time required to carry out the different duties done by shunting engines.

It is therefore necessary in each section to make a preliminary study of the work in the section, to separate it into all the elementary operations, to take a sufficient number of timings, both during the day and during the night and in all weathers, of these operations and starting from the information so collected to calculate the standard time corresponding to the different duties that the section may be called upon to do.

In view of the diversity of work carried out in any one section, and the multiplicity of details which occur during this work the task of determining the base figure for the output of each section is necessarily delicate and lengthy.

If we take into account that in a complete marshalling yard the number of sections is 5 or 6, it will be understood that getting out a scale of premiums for the whole of the marshalling yards of the system cannot be done in a moment [1], and that it is on the contrary the work of several years.

(1) In fact it is necessary to allow 6 to 8 months for each marshalling yard between starting the investigations, and the definite application of the output premiums.

As an example we will give later on particulars of the different operations which have had to be done in order to calculate the output of a section of a marshalling yard of the French Est Railway (section in which trains running towards Epinal and Strasbourg are formed in the Blainville marshalling yard).

The standard times corresponding to these different operations being supposed to be known for a section, the output per hour of shunting engines for a period of 24 hours will be determined in the following manner.

If we admit that it is possible to know the whole of the operations that the section has had to carry out during this period of 24 hours, obviously we can calculate the standard overall time allotted to the section for the whole of the operations by multiplying the standard time of each operation by the number of times it was done during the 24 hours and by adding up the whole of the products so got, when the ratio of the standard time to the time the engines are available during the period will give the desired output.

It is to be noted that according to the number of engines employed the operations can be done in different ways, when the standard times will therefore not be the same : there will therefore have to be different formulae according to the number of engines used (see the example given below for the same section of the Blainville marshalling yard).

The former average output will be calculated once for all by taking the time book and the operations which took place during the period of the enquiry in the section, and if needs be a check will be taken during a short test period before applying the premiums definitely.

Calculation of the time allotted to the section in which trains for Epinal and Strasbourg are formed in Blainville marshalling yard.

(Box A.)

The time Z allowed will be calculated by taking into account the work done by the engines, that is to say :

1. Of the total number of wagons passing over the hump excluding those marked off, or those the load of which has to be corrected when the defects are due to post A, and of the collectors that is . . . . A
2. Of the number of trains wholly formed by Box A (excluding trains formed by direct shunting) that is . . . . B
3. Of the number of trains partially formed by the direct shunting of a lot and in part formed by box A, that is C
4. Of the number of trains braked on the formation side by special operations from Box A, that is . D
5. Of the number of trains braked from the shunting side by special operations of the marshalling staff from Box A, that is . . . E
6. Of the number of shunts required to add wagons after the train is made up, that is. . . . . . . F
7. Of the number of trains from which marked off wagons have been withdrawn when the marking off took place after the trains had been formed, that is . . . G
8. Of the number of wagons to be attached in the rear put in place by special operations from Box A, which have been sent away, that is . . . . H

9. Of the number of rakes worked to the fan of arrival holding sidings with the assistance of the engine of Box A, that is . . . . N
10. Of the number of collectors shunted, that is . . . . P
11. Of the number of times the repair sidings are shunted, that is. R
12. Of the number of wagons under A increased by the number shunted direct, that is . . . . W
13. Of the number of pairs of wagons in the trains excluding pairs of loaded wagons and cuts of wagons, that is . . . . J
14. Of the number of rakes worked to the depot, that is . . . . . M

The time allowed Z, in minutes, is calculated by the following formulae :

1. *When one engine works the yard.*

$$Z = 0.15\ A + 26\ B + 13\ C + 5\ (D + E) + 4\ F + 9\ Gz + 5\ H + 12\ N + 0.8\ P + 20\ R + 7\ J + 0.10\ W + 12\ M.$$

2. *When two engines work the yard.*

$$Z = 0.15\ A + 30\ B + 15\ C + 5\ (D + E) + 4\ F + 9\ G + 5\ H + 12\ N + 0.8\ P + 20\ R + 7\ J + 0.10\ W + 6\ M.$$

If L is the total number of minutes during which the engine or engines under the marshalling Box A shall have been kept available for this section, the proportion indicated above shall be equal to

$$\frac{Z}{L}$$

Bonuses.

When calculating the work done only duties actually discharged by the section will be taken into account.

It may happen, however, that through the method by which the work is done that is to say without any additional engine shunting hours but solely by the intelligence displayed in doing it, a section economises a certain number of additional shunting hours which would have been required otherwise in other sections to do the work rendered unnecessary.

In this case, the saving in engine-minutes by which the whole of the shunting yard benefits is calculated, and a bonus in proportion thereto is granted to and equally distributed amongst the whole of the sections responsible.

For example, a bonus is allowed to the shunting yard when this yard makes it unnecessary for the formation yard to do part of its work by sending directly on to a train departure siding the wagons forming the train in question, or when a damaged wagon not marked off by the examiners is observed and is worked directly on to the sidings set aside for such wagons, thereby avoiding further shunting later on.

In the same way a bonus is distributed between the shunting out section and the train forming section when as a result of an agreement between these sections, the shunting out section can in time send straight to the front or rear of a train ready to leave a suitable brake and so enable the formation section to avoid having to make a special shunt to get a brake into position.

The study of the bonuses is of great importance owing to the very appreciable reduction properly devised bonuses can effect in the work of certain sections.

Penalties.

Contrariwise, when the work of a section is badly carried out a penalty is imposed. As in the case of the bonuses,

in each case enquiry is made as to the number of engine-minutes lost by the whole yard through the error of the section and a penalty proportional to this number of minutes is imposed on it.

For example, penalties are imposed on the shunting out section when it sends a wagon onto a line other than that for which it is intended and a penalty is imposed on the train formation section if a train leaves late.

As regards both bonus and penalty, the effect of the quality of the work done is of course determined beforehand, and when the nature of the operation carried out is stated, the corresponding bonus or penalty can be at once calculated.

Calculation of the collective premium.

In each section there are a certain number of boxes each worked by one man during the whole period the yard is open, that is with 1, 2, or 3 men if the yard is open 8, 16, or 24 hours. This staff constitutes the « theoretical establishment » of the section.

The collective premium is determined in the following manner.

The output obtained during a 24-hour-period decides the base value of the premium. This basic value is so calculated as to represent according to work done, from 5 to 37 % of the highest daily rate of pay a labourer can reach, that is to say a man in the lowest rated grade.

This basic value is multiplied by the number of men of each grade in the theoretical establishment, the total number of men of each grade being given a coefficient of majoration equal to the ratio between the maximum rate the men of this grade can reach, and the maximum a labourer can get; the collective premium is equal to the sum of these products.

If for an output R the basic value is T , if N, N_2, N_3, etc., are the theoretical numbers of men in grades 1, 2, and 3, etc., if K_2, K_3, etc., are the coefficients of majoration of grades 2, 3, etc., the collective premium will be :

$$G_c = T_R \ (N_1 + K_2 N_2 + K_3 N_3 + \text{etc.})$$

Individual premium.

This collective premium of the section is divided amongst the various men of the section who were actually on duty during the period under consideration and in proportion to the coefficient attributed to the grade of each man. The result is that if men are missing during this period, the premium of the men who were actually on duty grows proportionately : this increase constitutes a reward for the extra work involved by the absence of their mates.

Suppression of the premium.

Certain professional mistakes result in the suppression of the individual output premium of the men in fault.

For example : coming late on duty, failure to carry out an order, absence without permission, intemperance, careless working resulting in damage, etc.

Special premiums.

In addition there are other premiums of a more special kind.

1. For example, in the yards in which some of the men are responsible for reducing the speed of the wagons or for stopping them, a work of great importance owing to the damage that may result if the work is not properly done, such men can earn in addition to the premium for the section in which they

work, a special premium for braking wagons if the work is done satisfactorily.

Inversely, if the work is badly done, they are subject to a penalty which reduces their individual share in the premium due to them resulting from the output of their section.

A premium is awarded to them each time the number of damaged wagons per thousand is lower than the average number recorded prior to the institution of the premium scheme.

In this case the number per thousand damaged determines a coefficient of premium and the premium paid to each equals this coefficient multiplied by the number of wagons to be stopped in the whole section. The men in each section receive this premium increased by the coefficient of their grade.

On the other hand, when the number of damage cases per thousand is higher than the value prior to the institution of the premium system, each man has his premium reduced from 15 to 100 % according to the rate of damage cases reached during the period considered.

The same action is taken when the wagons, without actually being damaged, have the load so displaced that they have to be reloaded.

In addition each man in the section, responsible for stopping wagons and who is directly responsible for damage done or for a load that has moved, has his premium suppressed altogether.

2. Similarily, a special premium has been established for the tranship yard which handles parcels much as the yard as a whole handles wagons. As the actual work is done by a contractor, the special tranship premium only affects the supervising staff.

Each time during any one twenty-four hour-period the time allocated to transhipping compared with the time the contractor was employed reaches or betters the average time prior to the institution of the premium, a collective premium is awarded the whole of the supervising staff, the premium being the higher the more the average time is bettered.

The time allowed for transhipping is calculated by taking into account the number of tons of goods transhipped and the nature of the transhipment under the same conditions that the time allocated to a section is based on the number and kind of operations the section has to cover.

The basic value of this premium as a function of the output obtained is the same as that adopted for the collective premiums in the other sections of the yard.

The collective premium is also calculated in the same way as are the parts of the individual premiums.

Bonuses are also given the men whenever damage to goods or rolling stock for which the contractor is responsible is discovered.

On the other hand, penalties are imposed for example when through careless supervision the contractor avoids his responsibilities.

3. Further, besides the staff whose duties lie solely in a single section, there are others whose work or supervision effects several sections. Special solutions have been come to in each particular case : in principle these men are granted an average premium based on the work done in the various sections in whose work they take part.

These men know that they may ultimately receive bonuses or that fines may be imposed.

4. The station masters and assistant station masters are included in this cate-

gory. In addition they are penalised each time there is too great difference between the actual shunting engine-hours worked in the yard as a whole and the hours requisitioned for covering the yard services.

Adjustments in the case of frost.

In a yard where output premiums are not granted, the output in engine-hours undoubtedly falls as soon as the temperature drops appreciably and in particular as soon as it freezes.

In order to calculate the exact output of a twenty-four hour-period, it would not do to base it upon the standard times corresponding to the actual temperature on the day considered.

As it was impossible to arrive at these standard times by temperature before introducing the premium system, it was decided to calculate, no matter what the temperature, the output each day as a function of the ordinary standard times.

But each time during the 24-hour-period considered the temperature fell below 0° C. (32° F.), the output so obtained was increased by a certain coefficient which is equal to 1 when the minimum temperature equals 0, increases proportionately as the minimum temperature falls lower.

The coefficients established have been based on information collected when introducing the output premiums, this information forming however none too solid a foundation.

At the end of each winter, for each day in which the temperature fell below zero, the actual output of each yard was calculated, that is to say the output calculated from the standard times for average temperature without the use of any coefficient.

Moreover, using the results obtained in the yard with temperatures above 0° C. (32° F.), the most probable output for average temperatures, that is R, is calculated.

In addition, by grouping together the outputs obtained for minimum temperatures below 0°, the most probable output per temperature is calculated, that is :

$$r_{t-1} \quad r_{t\ 2} \quad r_{t-3} \text{ etc.}$$

The coefficient K_t by which must be multiplied for a minimum temperature below 0°, the output obtained starting from the usual formulae in order to take into account the supplementary difficulties caused by frost equals

$$K_t = \frac{R}{r_t}$$

Repeating this work after each winter for each yard, and in each yard for each section, a sufficient amount of information is ultimately obtained to calculate this coefficient K with close enough accuracy for each section and for each temperature. As a matter of fact, a single severe winter makes it possible to obtain almost final values.

Records.

In order to take into account the whole of the strictly necessary elements for calculating the outputs, the bonuses and the penalties in the different sections, it was necessary to collect a whole series of detail operations from note books, statements, and summaries.

In principle, the information is recorded in note books when this has to be carried by shunters out in the yard away from any office; the statements applying to particular cases are used when the information has to be given by the office staff. Finally the summaries are kept up

by the staff of a special office responsible for collecting, summarising and checking the detail statements, for ascertaining the output and for calculating the premiums.

As an example, below are given the details of the work done in the Blainville outwards train marshalling yard, for trains going in the direction of Strasburg and Epinal.

Details taken in the A yard at Blainville.

The assistant foreman shunter enters in a book;

the number of wagons pushed up the hump at post A;

the number of braked trains or of pushing trips for special shunts;

the number of cases of urgent wagons attached;

the number of trains from which defective wagons have been shunted out after the train has been formed;

the number of wagons marked off for the wrong line found in the rakes sent to the gravity hump when the mistakes are the result of wrong shunting;

Shunting to the reloading sidings.

The man in charge of the working prepares a statement showing :

the number of trains formed entirely by box A, or partly by box A and the shunting yard;

the trains braked by special shunt made by box A from the formation end or from the shunting end;

the number of shunts made by box A in order to add urgent wagons after the train has been made up;

the number of trains from which damaged wagons have been detached after forming the train;

the number of workings with engine in the rear;

the assisting engines used to work rakes of wagons and trains to the holding sidings;

the number of collectors shunted and the number of times the reloading sidings shunted;

the number of wagons directly shunted by box T;

the number of pairs of wagons included in the trains to the exclusion of brake wagons and groups of wagons;

the number of trains formed by box T by direct shunting;

the number of trains sent away late, the delay being due to the men in the section;

the number of trains partly formed by the direct shunting of a batch of wagons;

supplying a brake van, or working a train from the rear end done by box T by direct shunting;

the number of times a shunting engine or a train engine is used to remove a wagon on a wrong road, a wagon red labelled for repairs or for reloading through the fault of the section, or to add a brake by special shunt.

Following the shunting list, the times taken in the section by the engine or engines :

by adding the time taken by the engines of another section to shunt for box A :

by deducting the time taken by the engines of box A for shunts in other sections.

Central premium office.

This office staffed by the employee in charge with several men for checking the details of the work done in the sections and a certain number of others for the actual calculation, functions in the following way :

Each morning the checkers receive from the sections the details of the work done the previous day [1].

For each section they summarise on a statement for the whole 24-hour period the information supplied for each 8-hour period after checking it.

In order to do this they compare this information with that prepared either by the Staff Office (presence list of men) or by the Rolling Stock Office (delays, particulars of trains prior to leaving, rolling stock movements sheets).

They should also check the information given by one section against that of another. (For example : we have seen that a bonus is granted when a train is shunted directly. The men in the office dealing with output premiums should check that the train also appears at the same time on the foremen shunters' sheets, and on those of the marshalling of trains as having been shunted directly.

When the summary is drawn up for a section, other men determine on accounts forms, the output, the premiums, the penalties, the collective bonus, and the portion of the individual bonus due to the men of each grade. They transfer these latter on to a return which is posted up 16 hours after the end of each 24-hour period : the men of these sections can thereby learn the sums of money due to them for a given period not later than when coming on duty for the next period.

Between times the statement which has to be sent at the end of the month to Headquarters is drawn up : by means of it the staff can be paid at the end of the month the money for the 30-day period ending on the 15th of current month.

---

(1) Which ends at 4 a. m. the same day.

Results.

Through the institution of output premiums the following results have been obtained :

1. The output in engine-hours has been increased 17 % and the level of the possible output of the shunting yards has been raised by an equal amount.

2. The effect of the bonuses has been to incite the staff to work intelligently which has made it possible to lighten the work in the sections very materially by avoiding all work that could be suppressed by a better conception of the shunting in the sections where the work is started. The result has been a further increase in output in engine-hours of 3 % and at the same time an equal increase in the maximum output of the yards.

3. The penalties have sensibly reduced the mistakes which could be punished as well as errors in working and have resulted in almost entirely stopping wagons being sent on to wrong lines. Thanks to the latter fact the output in engine-hours has been improved by 2 % and the same applies to the possible output of the yards.

4. The bonuses for braking wagons have been successful and the number of damage cases has been halved.

5. At the tranship, the hourly output of the undertaking has been increased by nearly 20 %.

6. The station masters reduce to the minimum the requests for engines. The ratio of the time these engines are used to the time available has been increased by nearly 50 %; this increase is of course independent of the increases in output properly speaking indicated in the preceeding paragraph.

7. The improvements in the working

methods due to the introduction of the output premium has resulted in an improvement of the turn round of the stock in the yards wherein the time of the wagons has been reduced by 2 %.

8. The raising of the capacity of the yards as indicated in the preceding paragraphs has enabled at certain times volumes of traffic to be handled which previously would have made it necessary to open standby yards.

As a matter of information, the expenditure in the Blainville yard through the introduction of the premium system for a year was as follows :

Pay, including overhead charges of the premium system office	100 000 fr.
Payment of premiums to the men in the yards . .	230 000 fr.
Total . . .	330 000 fr.

The economies resulting from the increased output enumerated in the 6 first paragraphs, excluding No. 5, may be evaluated at :

For the 1st, 4 732 engine-hours	170 000 fr.
For the 2nd, 835 engine-hours	30 000 fr.
For the 3rd, 555 engine-hours	20 000 fr.
For the 4th, a reduction in damage of about. . . .	50 000 fr.
For the 6th, a saving of 2 946 engine-hours	101 000 fr.
Total . . .	371 000 fr.

It is hardly possible to calculate the savings under the other heading nor those due to the reduction in damage to goods.

The result is to show that the savings are largely superior to the cost of instituting the system.

SPECIMENS OF STATEMENTS

French Est Railway.

OPERATING.

1st DIVISION.

OUTPU

MONTH OF ....

Theoretical staff : { Men in gangs } .... Second class pointsmen Leading shunters .... } .... First class pointsmen Assistant foremen shunters } ....

EST. — FORM 5072.

Dates.	Minimum temperature of the day.	Coefficient of increase (°C.), column 3.	INDICES.															Z	Z increase according to coefficient C°., col. 3.	L	$\frac{\text{Z incr.}}{\text{L}}$	Corresponding base rate.	Bonuses.						Reductic		
																							(a) Several engines available in the section.				Not marked off on the way to the hump.	Total (b)	for wrong line.		
			Aj	An	B	F	G	E	M	U	T	V	S	W									G – 0.006	U – 0.006	T – 0.002	F 0.002			0.050	0.010	0.001
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

Copy of form 5072 for a shunting out section D, PANTIN station.

PREMIUMS.

.... 1929.

BOBIGNY SHUNTING YARD.

D

SHUNTING OUT SECTION.

oremen shunters .... Assistant station masters of ......class.. . Drivers Firemen ..

STATEMENT C.

				Number of men actually present of each grade.								Product of the coefficients, table 2 by the number of men of each grade present.											Corrected base rate.	Individual bonus actually, paid each man (no account taken of reductions or particular bonuses).							
in dispatching a train or in shunting.	Total (r)	Difference + or —	Net base rate.	Men.	Class 2 pointsmen.	Assistant foremen shunters.	Foremen shunters.	..... class assistant station masters.		Drivers.	Firemen.	Men.	Class 2 pointsmen.	Assistant foremen shunters.	Foremen shunters.	..... class assistant station masters.		Drivers.	Firemen.	Total of columns 53 to 60.	Sum of the products of the coefficients of table 2 of the General Instruction for the theoretical staff.	Quotient of column 62 by column 61.	Product of column 44 by column 63.	Men.	Class 2 pointsmen.	Assistant foremen shunters.	Foremen shunters.	..... class assistant station masters.		Drivers.	Firemen.
34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65

FRENCH EST RAILWAY.	OUTPUT PREMIUMS.	PAGE 1.
OPERATING.	Year 192........................	BOBIGNY. Shunting yard.
1st Division.	Day : from .... to .... Date : from .... to	D.
Weather.	Period : from ....o'clock to.....................o'clock.	Shunting out section.
EST. — FORM 5081.		STATEMENT W.

Number of the sidings pushed back for shunting.	Number of wagons shunted.	Shunting		Pushing back		Pushing up		Waiting	
		from	to	from	to	from	to	from	to
1	2	3	4	5	6	7	8	9	10

PARTICULARS CONCERNING THE ENGINES

Engine numbers.	Names of the		Available		PARTICULARS NOTES. Accidental interruptions, reason of interruption with indication, if required, of the responsible service; interrupted through lack of work, cleaning fires, taking water, working in another section, etc.
	drivers.	firemen.	from	to	

Specimen of form 5081, head of shunting service D, PANTIN station.

Day — Date — Period.	Number of wagons shunted off.		Number of rakes shunted.	Number of Noisy rakes pushed up from yard D and placed ready for leaving.			Shunting on to the repair siding the units for it.			Number of shunds needed to work on to the making up siding of the marshalling section V a lot taken from fan N or V.				Numbers of the trains cancelled in which the collectors have had to be reversed in the exchange trains for Vaires or Gretz.	Trains braked Noisy end by special operations.	Trains formed by other sections from which wrong line wagons or damaged wagons have been shunted out when the damage is not the result of a shunt made after the formation of the train.				Addition of express wagons after the formation of the train.	Trains to which the collectors have been added by a special operation.
	By day (1)	By night (1)		at the fan of sidings		Number of wagons	Sidings shunted			Siding taken from marshalling section V.	Time taken away from V.	Reception siding in the fan			Numbers of the trains.	Wrong line.	Train number.	Damage (2)	Train number.	Train numbers.	Train numbers
				N	V		Nos	from	to			N.	V.								
	Aj	An	B	M		W	E			V				S	F	G				U	T
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		18		19	20
															A single engine is at the disposal of the section.						
															Two engines are at the disposal of the section.						

BONUSES (3)

MARKED OFF ON THE WAY TO THE GRAVITY HUMP.

Company.	Class.	Numbers of the wagons.	Company.	Class.	Numbers of the wagons.

(1) The hours of day and night are calculated according to item 10, page 19 of No. 1 heading of the Instruction. (2) Attach to the statement the repair cards sent in by the maintenance staff. (3) Attach note signed by examiner on duty.

FRENCH EST RAILWAY.

OPE·ATING.

1st Division.

EST. — FORM. 5087.

OUTPU

SUMMARY STATEMENT

Day : *from the*.......................... .. *at* ..

Period fro

FIRST CASE : Onl

Periods.	Engine numbers.	Hours used.		Duration of work.		Number of wagons shunted		Number of times wagons pushed up.	Noisy rakes worked from D to N or V. Number		Number of times repai sidings shunted.
		from	to	in hours.	in minutes.	day.	night.		of rakes.	of wagons.	
						Aj	**An**	**B**	**M**	**W**	**E**
1	2	3	4	5	6	7	8	9	10	11	12
6 a. m. to 2 p. m.											
2 p. m. to 10 p. m.											
10 p. m. to 6 a. m											
Totals											

SECOND CASE

						Aj	**An**		**M**		**E**
6 a. m. to 2 p. m.								The index B is not used.		The index W is not used.	
2 p. m. to 10 p. m.											
10 p. m. to 6 a. m.											
Totals.											

(1) The indices **F G U T** are not taken into account into the formula

	BONUSES.	REDU	
		NUMBER OF WRONG LINE	
	Number of wagons found damaged on the way to the hump advised on form 5056 as per copy attached.	At zone P of a wagon for zone D.	At a section of zone D of a wagon for another section.
	0.006	0.050	0.010
6 a. m. to 2 p. m.			
2 p. m. to 10 p. m.			
10 p. m. to 6 a. m.			
	× 0.006 =	× 0.050 =	× 0.010 =

Copy of form 5087. — Summary for 24 hours of information supplied by a section, shunting D, Pantin station.

PREMIUMS.

BOBIGNY.

Shunting yard.

D SHUNTING SECTION.

Date : *from the* .... *at*..*192*.........

6 to 6 a. m.

STATEMENT Q.

one engine available.

Number of shunts on make-up siding V of a lot from N or V.	Number of trains suppressed the collectors of which have been attached to the Vaires or Gretz rakes.	Number of trains braked Noisy end.	Number of trains from which damaged wagons or wrong line wagons have been withdrawn.	Number of shunts for urgent wagons.	Number of trains to which collectors have been attached.	*REMARKS.*
V	**S**	**F**	**G**	**U**	**T**	
13	14	15	16	17	18	

Two engines available.

V	**S**	**F** (1)	**G** (1)	**U** (1)	**T** (1)
		0.002	0.006	0.006	0.002

They can affect the calculation of the premiums in the form of bonuses.

TIONS.

GONS ON THE SIDING CONSIDERED.		Extent of delays attributable to the shunting D. 0.010 par 2′
At box D of a wagon intended for this box. 0.001	At the box V of a wagon for this box. 0.001	
		Total of the three periods. $\left\} \dfrac{\times 0.01}{2} = \right.$
$\times 0.001 =$	$\times 0.001 =$	

Copy of note book pattern 5107. Assistant foreman shunter, D shunting yard PANTIN. (*See page* 1997 *for continuation*).

(1)
Number of times wagons pushed up.
(B).

Time		Taken from sidings.	Number of wagons.
from	to		

(1)
Number of times wagons pushed up.
(B).

Time		Taken from sidings.	Number of wagons.
from	to		

Copy of note book number 5107 *(continued)*.

(2)

Pushing up from 27 D.
(E).

Number of times.	Time taken.	
	from	to

Wagons not marked off found damaged
on way to hump
and shunted directly on to siding 27.

Number of the wagon.	Number of the wagon.	Number of the wagon.

(3)

Work done by engines.

Number	Section using.	From	To	*Notes.*

FRENCH EST RAILWAY.

OPERATING.

1st Division.

OUTPUT PREMIUMS.

SECTION ______________________

BOBIGNY.

SHUNTING YARD

STATEMENT O.

INDIVIDUAL BONUSES granted undermentioned employees

For the ______________________ (Date)

EST. — FORM 5120.

Names.	Grades.	Amount of premiums granted.	Names.	Grades.	Amount of premium granted.

Copy of form 5120, daily list of premiums obtained, Pantin station.

STATEMENT

OF INDIVIDUAL PREMIUMS.

FRENCH EST RAILWAY.

OPERATING.

1st Division.

EST. — FORM 5118.

OUTPUT

STATEMENT OF IN

Grades. (1)	Names of the men.	Section.	Employed as.	DA														
				16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
				AMOUNT OF THE IN														

(1) Drivers and firemen are not to be included.

Specimen of form 5118. Individual gratuities obtained in the course of one month, Pantin station.

PREMIUMS.

BOBIGNY
SHUNTING YARD.

IDUAL PREMIUMS.

STATEMENT **J.**

Month of ________ *192*__.

ES															Total.	Reductions. (2)	Remainder.	*Notes.*
	2	3	4	5	6	7	8	9	10	11	12	13	14	15				
IDUAL PREMIUM.																		

(2) Special reductions for individual faults.

NEW BOOKS AND PUBLICATIONS.

[621 33]

HÖRING (O.), Regierungsbaumeister, Prokurist der Siemens-Schuckertwerke, A.-G. — **Elektrische Bahnen** (**Electric Railways**). — One volume (8 1/4 × 6 inches), 515 pp., 502 figures, 9 tables of numerical data, 1 map and 8 plates. — 1929, Berlin and Leipzig, Walter de Gruyter & Co. (Price : 15 Rm).

This book forms the fifteenth volume of the Siemens collection of handbooks, edited by the firms Siemens & Halske A.-G. and Siemens-Schuckertwerke A.-G. Its various chapters review all the branches of the vast subject of the applications of electricity to traction, and have been written with the collaboration of specialists of these two great electrical engineering firms.

The author recalls in the first place the rapid development of electric traction, which, in the course of half a century, has become absolutely essential in the sphere of the tramways, and although the length of main line electric railways is as yet relatively small [13 723 km. (8 528 miles) for the whole world], it is growing rapidly year by year.

Chapter II covers the difficulties of a technical, economical and even strategic nature, which electric railways properly so-called have met with in their development.

The author then proceeds to detail the plan of the book, giving the general classification of electric railways, comprising : *a*) railways which make use of streets or roads (tramways, suburban railways) ; *b*) railways which have their own track (elevated or underground metropolitan railways, main line railways, rack railways) ; *c*) industrial railways.

Chapter IV enters into the developments relating to the study of the designs of electric railways : conditions governing the construction of the line, evaluation of the probable traffic, constructing the time-table graphs, composition of the trains, choice of current to be used : discussion of the D. C., three-phase and single-phase systems; the elements of the calculations relating to electrical installations are then considered : resistance of the vehicles and trains, calculation of the motive power of the coaches or locomotives, calculation of the capacity of the central power station and sub-stations, calculation of the line. This chapter contains numerous diagrams, tables of practical data, examples showing the application of the formulæ and the methods of calculation.

Chapter V, the most important chapter of the book, comprises a very detailed study, from both the mechanical and electrical points of view, of the three great sub-divisions : *a*) tramway vehicles and suburban railway vehicles; *b*) electric locomotives properly so-called; *c*) rail motor cars and tractors.

In Chapter VI, the book then proceeds to discuss the special conditions relating to the establishment and working of central power stations and sub-stations intended to supply current to traction lines. A detailed study of the construction of the track and the installation of the contact lines forms the subject-matter of Chapter VII, which also deals with the accessory track installations. Finally, the questions relating to the disturbances in telephone and telegraph lines caused by electric traction are discussed, together with the means for remedying them.

Two chapters are devoted to the study

of different types of industrial railways, rack railways and suspended railways, and the book is brought to a close by a detailed chapter on the questions involved in operating electric railways : professional training of the employees; inspection, maintenance and repair of the rolling and fixed stock; equipment of repair workshops and stations.

This short analysis shows the importance of the matter which has been dealt with in this handbook. The arrangement is clear and methodical, the book has been got up with particular care, and the many illustrations and diagrams make reading pleasant and easy. In the past few years, the technical literature has been enriched by important treatises dealing with the various portions of this branch of electrical engineering, and noteworthy articles have appeared on this subject in the technical press. Mr. Höring's handbook, without having the scope of these special works, condenses the matter into a precise account of the present state of this branch of engineering. There is no doubt that, from this point of view, it will be appreciated by the higher educational institutions, that it will be read with interest by the technician who wishes to keep himself informed of the progress made in this sphere, and that it will even be consulted occasionally with profit by the professional railway electrical engineer.

A. C.

[621. 592 & 624. 92]

Précis de la construction des charpentes soudées (**Summary of the construction of welded framed structures**). — One volume (9 × 6 inches), 112 pages, 142 figures and 3 plates. — 1929, Brussels, Editions Arcos. La Soudure Electrique Autogène, S A., 90, Avenue du Pont de Luttre.

This work marks a stage in the development of electric arc welding. Everyone is acquainted with the services which this method has rendered in railway repair shops. During the past few years, arc welding has found application in constructional work, but in this sphere preliminary studies and a more advanced technique than in repair work have been necessary.

The firm « La Soudure Electrique Autogène », which has made this problem its speciality, has carried out, in collaboration with the laboratories of the Brussels University, a systematic research and experiments with this object in view, which have enabled the underlying principles of the new technique to be ascertained.

It is the results of these experiments, and the rules of calculation thus determined, which have just been published.

In the first part of the volume, welded parts are studied from the point of view of the mechanical properties of the deposited metal, and then as regards assembling laminated pieces. The specific strengths of different types of welded joints are examined in detail.

An important chapter is devoted to the general rules of calculating welded joints. By means of examples selected from everyday practice, it is shown how essential it is to design the welded construction quite distinct from any idea of copying, or adapting it to, riveted structures.

As a practical application of the methods developed in the book, a study is made of a framework of a definite type, with the calculations and complete drawings for a girder and its welded joints.

The economical point of view has not been neglected. In chapter VI, the

constructor will find the data required for drawing up an estimate of the cost of a welded framed structure, so that he may compare it with that of the ordinary rivetted construction.

One objection which is often raised lies in the difficulty of erection. The book shows that this difficulty hardly exists, and the constructor has a choice of several methods which are explained in detail.

The application of electric welding in special cases, such as oblique cuts in the slopes of roofs, irregular outlines, etc., are then considered. Even if electric arc welding is not resorted to generally, it often enables certain special difficulties to be solved and time to be saved.

The regulations governing welding, an essential factor of safety, receive special treatment. A detailed list of standard specifications has been drawn up for the inspection of electrodes, the control of welded parts and the professional qualifications of the welders.

Chapter X deals with the methods of checking welded structures after they have been completed. The book closes with a discussion of the precautions to be taken by welders, and with an account of the experiments carried out at the Brussels University.

The *Prècis de la construction des charpentes soudées* forms a survey of the whole field of an art which is certain to make great strides. The book breaks new and little known ground.

We feel that we should point out that this book, although published by an industrial firm, is quite free from any advertising spirit. It forms a serious contribution, based on scientific data, to the development of the method of assembling structures by electric arc welding, and it will certainly interest all who are occupied with the construction of framed structures.

A. C.

[**016**. 385 (.494)]

Library Catalogue of the Swiss Federal Railways. — One volume (10 × 7 inches), 227 pages. — 1928. Berne, published by the General Direction of the Swiss Federal Railways.

It would not have been necessary to comment here upon this catalogue, if it had not possessed a remarkable feature and one worthy to be mentioned to the readers of the *Bulletin*. Our readers know that for a very long time the International Railway Congress Association has made use of the decimal system of classification. This system has rendered very great service and at the present time is being used to some extent everywhere, especially in workshops and research departments. The information which every intellectual worker requires becomes more and more abundant as technology progresses and becomes more complicated, and a systematic classification is necessary if the information is to be made fully useful.

Mr. E. Mathys, librarian of the General Direction of the swiss Federal Railways, has taken advantage of the valuable resources of the decimal system of classification and, using it as a basis, has compiled a very practical catalogue. It will be understood that a classification which proceeds by ideas and from the general to the particular is infinitely superior to the alphabetical order, in itself unreliable, in a country where there are three official languages.

At the beginning of the book will be found an indication of the classes and a certain number of sub-classes in the three languages. This in itself should be a sufficient guide in making searches. Nevertheless, an alphabetical list of all the sub-divisions which the classification already comprises, enables the number under which the desired information will be placed, to be found very quickly.

E. M.